

# NATIONAL GEOGRAPHIC

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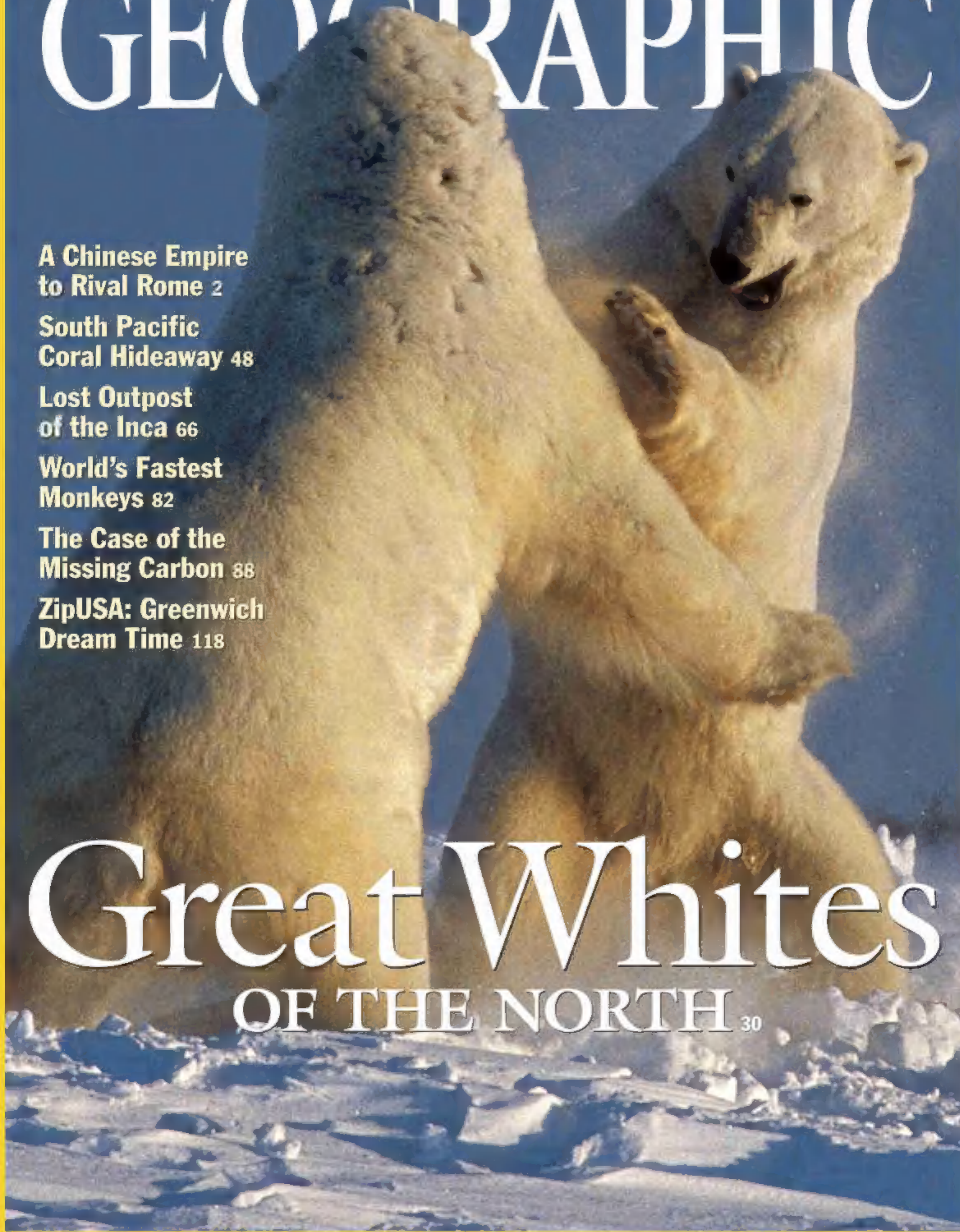
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# Great Whites

OF THE NORTH 30





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### THE COVER

Polar bears tussle on the tundra near Hudson Bay.

BY NORBERT ROSING

♻️ Cover printed on recycled-content paper

### ON THE WEBSITE

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# OnScreen & Online

## National Geographic Channel



MARCH 1, 9 P.M. ET/10 P.M. PT

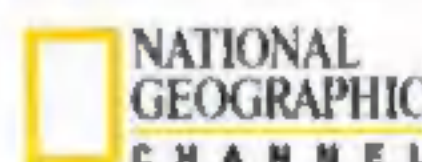
### The Kennedy Mystique: Creating Camelot

He was young and handsome, she aristocratic and glamorous. When John and Jackie Kennedy moved into the White House, a new age of style—and image-making—began in American politics. This provocative documentary, with rarely seen photographs, takes you into the private life of the Kennedy first family, where personal struggle and public image were often at odds.

THURSDAYS, 8 P.M. ET/9 P.M. PT

### Dangerous Jobs

Join race car drivers as they hurtle around corners at breakneck speeds, firefighters as they put their lives on the line to control a blaze (right), and a cameraman as he confronts an onrushing hurricane. None of them do what they do for money or fame. They all say they do it because they love their work—and the risks that come with dangerous jobs.



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SUNDAYS, 8 P.M.  
ET/PT

### Kratt Brothers: Be the Creature

Eating bark, making snowballs, and venturing into a volcanic pool, Chris and Martin Kratt share in the world of Japanese snow monkeys as the filmmakers strive to “be the creature.”

Channel and NGT&F programming information accurate at press time; consult local listings or the Society's website at [nationalgeographic.com](http://nationalgeographic.com)

## NG Television & Film



NATIONAL GEOGRAPHIC ULTIMATE EXPLORER  
MSNBC, SUNDAY, FEBRUARY 22, 8 P.M. ET/PT

### Into the Lost World

A thousand feet below climber Jared Ogden (left) stretches untracked Guyana jungle; above rises Mount Roraima, a 9,000-foot-high tepui, the Pemón Indian word given to these bizarre, towering mesas. Correspondent Mireya Mayor joins scientists and climbers in a natural history adventure to study plants and animals of the remote tepui world.

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### BLACK HISTORY MONTH

**YOU ARE A SLAVE IN 1850s MARYLAND** Escape on our interactive Underground Railroad with Harriet Tubman (right). **PAST AND PRESENT** Ride the West with African-American cowboys, travel the “blues highway,” and take a look at South Africa on the tenth anniversary of the end of apartheid. [nationalgeographic.com/history](http://nationalgeographic.com/history)



### SIGHTS & SOUNDS OF CHURCHILL'S POLAR BEARS

**POLAR BEARS IN ACTION** See exclusive video footage of polar bears playing near Hudson Bay.

**POSTCARDS** E-mail a polar bear photo to a friend. [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402)

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*– Mike Ditka, NFL Hall of Fame player and coach*

\* Among orally administered ED treatments.  
† Individual results may vary.

Please see adjacent Patient Information for more about LEVITRA (2.5 mg, 5 mg, 10 mg, and 20 mg) tablets.

LEVITRA is a medicine that may be used up to once a day to treat erectile dysfunction (ED). LEVITRA is for use by prescription only. Men taking nitrate drugs, often used to control chest pain (also known as angina), should not take LEVITRA. Men who use alpha-blockers, sometimes prescribed for high blood pressure or prostate problems, also should not take LEVITRA. Such combinations could cause blood pressure to drop to an unsafe level. The most commonly reported side effects are headache, flushing, and stuffy or runny nose. Men who experience an erection for more than four hours should seek immediate medical attention. You should not take LEVITRA if your doctor determines that sexual activity poses a health risk for you. LEVITRA does not protect against sexually transmitted diseases.



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**Patient Information**  
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**(vardenafil HCl) Tablets**

08669034IP

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Read the Patient Information about LEVITRA before you start taking it and again each time you get a refill. There may be new information. You may also find it helpful to share this information with your partner. This leaflet does not take the place of talking with your doctor. You and your doctor should talk about LEVITRA when you start taking it and at regular checkups. If you do not understand the information, or have questions, talk with your doctor or pharmacist.

**WHAT IMPORTANT INFORMATION SHOULD YOU KNOW ABOUT LEVITRA?**  
LEVITRA can cause your blood pressure to drop suddenly to an unsafe level if it is taken with certain other medicines. With a sudden drop in blood pressure, you could get dizzy, faint, or have a heart attack or stroke.

**Do not take LEVITRA if you:**

- take any medicines called "nitrates."
  - use recreational drugs called "poppers" like amyl nitrate and butyl nitrate.
  - take medicines called alpha-blockers.
- (See "Who Should Not Take LEVITRA?")

**Tell all your healthcare providers that you take LEVITRA.** If you need emergency medical care for a heart problem, it will be important for your healthcare provider to know when you last took LEVITRA.

**WHAT IS LEVITRA?**

LEVITRA is a prescription medicine taken by mouth for the treatment of erectile dysfunction (ED) in men.

ED is a condition where the penis does not harden and expand when a man is sexually excited, or when he cannot keep an erection. A man who has trouble getting or keeping an erection should see his doctor for help if the condition bothers him. LEVITRA may help a man with ED get and keep an erection when he is sexually excited.

**LEVITRA does not:**

- cure ED
- increase a man's sexual desire
- protect a man or his partner from sexually transmitted diseases, including HIV. Speak to your doctor about ways to guard against sexually transmitted diseases.
- serve as a male form of birth control

LEVITRA is only for men with ED. LEVITRA is not for women or children. LEVITRA must be used only under a doctor's care.

**HOW DOES LEVITRA WORK?**

When a man is sexually stimulated, his body's normal physical response is to increase blood flow to his penis. This results in an erection. LEVITRA helps increase blood flow to the penis and may help men with ED get and keep an erection satisfactory for sexual activity. Once a man has completed sexual activity, blood flow to his penis decreases, and his erection goes away.

**WHO CAN TAKE LEVITRA?**

Talk to your doctor to decide if LEVITRA is right for you.

LEVITRA has been shown to be effective in men over the age of 18 years who have erectile dysfunction, including men with diabetes or who have undergone prostatectomy.

**WHO SHOULD NOT TAKE LEVITRA?**

**Do not take LEVITRA if you:**

- take any medicines called "nitrates" (See "What important information should you know about LEVITRA?"). Nitrates are commonly used to treat angina. Angina is a symptom of heart disease and can cause pain in your chest, jaw, or down your arm. Medicines called nitrates include nitroglycerin that is found in tablets, sprays, ointments, pastes, or patches. Nitrates can also be found in other medicines such as isosorbide dinitrate or isosorbide mononitrate. Some recreational drugs called "poppers" also contain nitrates, such as amyl nitrate and butyl nitrate. Do not use LEVITRA if you are using these drugs. Ask your doctor or pharmacist if you are not sure if any of your medicines are nitrates.
- take medicines called "alpha-blockers." Alpha-blockers are sometimes prescribed for prostate problems or high blood pressure. If LEVITRA is taken with alpha-blockers, your blood pressure could suddenly drop to an unsafe level. You could get dizzy and faint.
- you have been told by your healthcare provider to not have sexual activity because of health problems. Sexual activity can put an extra strain on your heart, especially if your heart is already weak from a heart attack or heart disease.
- are allergic to LEVITRA or any of its ingredients. The active ingredient in LEVITRA is called vardenafil. See the end of this leaflet for a complete list of ingredients.

**WHAT SHOULD YOU DISCUSS WITH YOUR DOCTOR BEFORE TAKING LEVITRA?**

**Before taking LEVITRA, tell your doctor about all your medical problems, including if you:**

- have heart problems such as angina, heart failure, irregular heartbeats, or have had a heart attack. Ask your doctor if it is safe for you to have sexual activity.
- have low blood pressure or have high blood pressure that is not controlled
- have had a stroke
- or any family members have a rare heart condition known as prolongation of the QT interval (long QT syndrome)
- have liver problems
- have kidney problems and require dialysis
- have retinitis pigmentosa, a rare genetic (runs in families) eye disease
- have stomach ulcers
- have a bleeding problem
- have a deformed penis shape or Peyronie's disease
- have had an erection that lasted more than 4 hours
- have blood cell problems such as sickle cell anemia, multiple myeloma, or leukemia

**CAN OTHER MEDICATIONS AFFECT LEVITRA?**

Tell your doctor about all the medicines you take including prescription and non-prescription medicines, vitamins, and herbal supplements. LEVITRA and other medicines may affect each other. Always check with your doctor before starting or stopping any medicines. Especially tell your doctor if you take any of the following:

- medicines called nitrates (See "What important information should you know about LEVITRA?")
- medicines called alpha-blockers. These include Hytrin® (terazosin HCl), Flomax® (tamsulosin HCl), Cardura® (doxazosin mesylate), Minipress® (prazosin HCl) or Uroxatral® (alfuzosin HCl).
- medicines that treat abnormal heartbeat. These include quinidine, procainamide, amiodarone and sotalol.
- ritonavir (Norvir®) or indinavir sulfate (Crixivan®)
- ketoconazole or itraconazole (such as Nizoral® or Sporanox®)
- erythromycin
- other medicines or treatments for ED

**HOW SHOULD YOU TAKE LEVITRA?**

Take LEVITRA exactly as your doctor prescribes. LEVITRA comes in different doses (2.5 mg, 5 mg, 10 mg, and 20 mg). For most men, the recommended starting dose is 10 mg. **Take LEVITRA no more than once a day.** Doses should be taken at least 24 hours apart. Some men can only take a low dose of LEVITRA because of medical conditions or medicines they take. Your doctor will prescribe the dose that is right for you.

- If you are older than 65 or have liver problems, your doctor may start you on a lower dose of LEVITRA.
- If you are taking certain other medicines your doctor may prescribe a lower starting dose and limit you to one dose of LEVITRA in a 72-hour (3 days) period.

Take 1 LEVITRA tablet about 1 hour (60 minutes) before sexual activity. Some form of sexual stimulation is needed for an erection to happen with LEVITRA. LEVITRA may be taken with or without meals.

Do not change your dose of LEVITRA without talking to your doctor. Your doctor may lower your dose or raise your dose, depending on how your body reacts to LEVITRA.

If you take too much LEVITRA, call your doctor or emergency room right away.

**WHAT ARE THE POSSIBLE SIDE EFFECTS OF LEVITRA?**

The most common side effects with LEVITRA are headache, flushing, stuffy or runny nose, indigestion, upset stomach, or dizziness. These side effects usually go away after a few hours. Call your doctor if you get a side effect that bothers you or one that will not go away.

**LEVITRA may uncommonly cause:**

- an erection that won't go away (priapism). If you get an erection that lasts more than 4 hours, get medical help right away. Priapism must be treated as soon as possible or lasting damage can happen to your penis including the inability to have erections.
- vision changes, such as seeing a blue tinge to objects or having difficulty telling the difference between the colors blue and green.

These are not all the side effects of LEVITRA. For more information, ask your doctor or pharmacist.

**HOW SHOULD LEVITRA BE STORED?**

- Store LEVITRA at room temperature between 59° and 86° F (15° to 30° C).
- Keep LEVITRA and all medicines out of the reach of children.

**GENERAL INFORMATION ABOUT LEVITRA.**

Medicines are sometimes prescribed for conditions other than those described in patient information leaflets. Do not use LEVITRA for a condition for which it was not prescribed. Do not give LEVITRA to other people, even if they have the same symptoms that you have. It may harm them.

This leaflet summarizes the most important information about LEVITRA. If you would like more information, talk with your healthcare provider. You can ask your doctor or pharmacist for information about LEVITRA that is written for health professionals.

For more information you can also visit [www.LEVITRA.com](http://www.LEVITRA.com), or call 1-866-LEVITRA.

**WHAT ARE THE INGREDIENTS OF LEVITRA?**

**Active Ingredient:** vardenafil hydrochloride

**Inactive Ingredients:** microcrystalline cellulose, crospovidone, colloidal silicon dioxide, magnesium stearate, hypromellose, polyethylene glycol, titanium dioxide, yellow ferric oxide, and red ferric oxide.

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PETER ESSICK (ALL)

## So what's the big deal about carbon?

Some of you will probably ask that question when you come to page 88 and find "The Case of the Missing Carbon."

Carbon is crucial to life. It's in the air and water, in decaying leaves and burning logs, in chunks of coal and glittering diamonds, in every plant and animal. It circulates through the environment in a cycle as intricate as the workings of a fine Swiss watch.

But humans are throwing the carbon cycle out of whack. With the burning of fossil fuels to feed our enormous appetite for energy, we've released as much carbon into the atmosphere in the past 30 years as we had in the previous two centuries. This really hits home when I read that the U.S. is responsible for emitting more carbon by far than any other nation. Humans are accelerating global warming with potentially dangerous side effects.

Right now the Earth sponges up more than half the carbon we release. But exactly where is it? And how long will it stay there?

I know that some people find science articles daunting. But think of this one also as a mystery story. The future of the planet may depend on the solution.

*Bill Allen*



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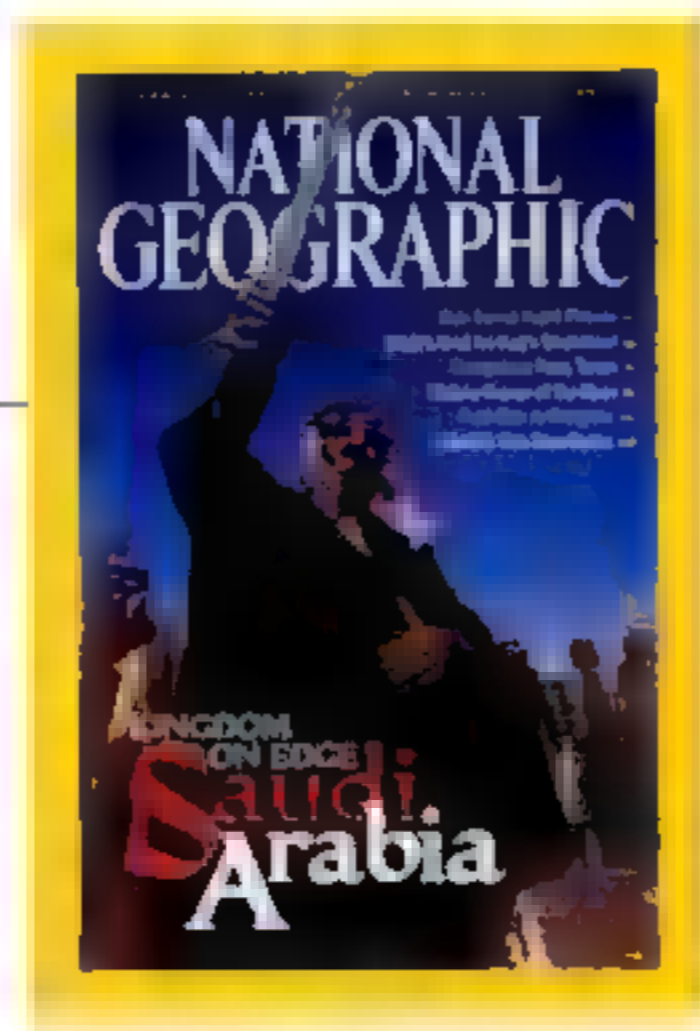
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# Forum

## October 2003

The cover story on Saudi Arabia, "Kingdom on Edge," elicited the strongest reaction—both positive and negative—from our readers. The Saudi government also had a strong reaction: Its Ministry of Information banned sale of the issue on newsstands throughout the country. News of that action prompted one Canadian reader to write, "What got them so upset? Could it be that the truth hurts?"



## Saudi Arabia

Bravo to writer Frank Viviano and photographer Reza for their compelling portrait of a complex and turbulent land. In almost every image and paragraph, one sensed the wrenching social upheaval oil has spawned there since being tapped on March 3, 1938. Now one wonders whom to feel worse for—imported low-wage workers or the nation's youthful slackers.

JAY ALLAIN

Stonington, Connecticut

"Kingdom on Edge" was a real mind-opener. The author's accounts of liberalizing forces within the kingdom are truly encouraging. I remain unconvinced, though, that these internal forces alone will prevail against Saudi Arabia's intolerant Wahhabi theocracy. The influence on government by religious

officials who are regarded as divinely guided is a force that should not be taken lightly. Unfortunately, the Wahhabi fear and hatred of secularism and non-Islamic religions is not confined to the Saudi kingdom. The Saudis are eager and able, with their petrodollars, to export their Wahhabi theocracy throughout the world.

JOHN NEHRING

Helena, Montana

Why would a venerable institution like NATIONAL GEOGRAPHIC run a public relations story for Saudi Arabia? Do you think your subscribers don't know that Saudi Arabia is the primary sponsor of Muslim terrorism in the world today? We're not as gullible as the Saudis hope we are.

ED HARDIMAN

Arlington, Virginia

Your report on Saudi Arabia was informative, fair, and impartial. I agree with Editor Bill Allen when he writes in From the Editor that the story is "essential reading for those who won't settle for stereotypes." Since the events of 9/11, the kingdom has been the subject of numerous negative reports from the American press. It should be remembered that in

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### Iraq's Antiquities

As someone who has been involved in Iraq advocacy work since 1996, I am all too aware of the toll that years of conflict have had on both the Iraqi people and their nation's cultural heritage. The inevitable loss of life in war is devastating, but there is also something horrific about the destruction of archaeological sites that hold still unknown secrets of the history of civilization. I hope your article generates the outrage and action necessary to save what remains, lest we lose our past forever.

BETH LAVOIE  
Atlanta, Georgia

Archaeologists would do well to use their knowledge to help uncover the thousands of murdered lying in mass graves.

If this human tragedy is of no interest to archaeologists, what difference does it make to seek to unravel more ancient events?

ROBERTO HEALY  
Houston, Texas

I cannot see how looting is going to stop until Iraq becomes a peaceful, abundant place to live. People existing on the margins of human existence are never going to look upon a source of cash with anything more elevated than brigand lust. So would I if my family was living hand to mouth.

MERLIN DOUGLAS LARSEN  
West Jordan, Utah  
FROM OUR ONLINE FORUM  
[nationalgeographic.com/ngm/0310](http://nationalgeographic.com/ngm/0310)

It was jarring to see the photo of photographer Randy Olson



MATT MOYER. WORLDPICTURENEWS

on page 68. He's smiling as though he were sightseeing somewhere, while behind him is another example of the destruction of what was once a vibrant nation.

JEHANNE MOHARRAM  
Alexandria, Egypt

Randy Olson says it was the awkward smile of a man struck by the absurdity of posing for a quick portrait in the middle of a war zone. "The only word to describe the moment," says Olson, "is incongruous."

1991, both Israel and Saudi Arabia were targets for Scud missiles from Saddam Hussein.

BURT SILVERSTEIN  
Le Cannet, France

I do not understand why you chose a sword-wielding prince for the cover of your October 2003 issue. Bill Allen tells us that your story on Saudi Arabia is "essential reading for those who won't settle for stereotypes." But doesn't the magazine's cover photograph promote the stereotype that Saudis and Arabs are

backward and bloodthirsty?

URSULA SCHREFFLER  
Dillsburg, Pennsylvania

I couldn't help but notice that almost all the men pictured in the article are wearing the same red-and-white headdresses. Why red and white?

CLINT GREENBAUM  
Westhampton Beach, New York

*Until the early 20th century two types of headdresses, or kaffiyehs, were most commonly used in the Middle East: black and white, typically worn by Bedouin, and pure white, often worn by men in cities and villages. During World War I the British Army introduced red-and-white kaffiyehs for the Jordanian Army. The red-and-white headdresses then spread throughout the region (including Iraq, as in the picture above).*

### Mongolian Crossing

A few years ago I was a student at the Santa Fe photography workshops under the tutelage of NATIONAL GEOGRAPHIC photographer David Alan Harvey. One of my classmates stood out because he never seemed to be able to sit in a chair. He would always squat with his feet on the chair seat as though he were on a rock ledge. He specialized in adventure and mountaineering photography; he took Mr. Harvey's class to find a more human side in his work. The student's name was Gordon Wiltsie. After seeing the Mongolia piece, I wanted to write: Gordon, I think you passed the course.

DAVID ZALAZNIK  
Peoria, Illinois

I once spent about four weeks on horseback in and around the

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Darhad and Lake Hovsgol. In Mongolia the nomad's creed of never turning away a visitor is still entrenched in the culture. I believe I could have made my journey without tent or supplies and never been stuck for a tent (or *ger*) to rest in or a plate of mutton to keep me upright in the saddle. It never fails to impress me how a genuine welcome can almost always be found even in the most wretched hovel, yet a penthouse door on Park Avenue is seldom likely to swing open when you need it most.

RICHARD SIBERRY  
*Farmingdale, New York*

### Maya Water World

I spent last spring in Yucatán at an archaeology field school, where I slept in a tent next to a cenote for three months. It is easy to understand why the ancient Maya held such reverence for these sacred pools. After jumping into one pool 30 feet below me, I really felt like I was falling into the underworld.

BRAD GARRETT  
*Riverside, California*

I was quite intrigued by the notion of the cenotes draining underground to the sea, but one thing puzzles me. The article states that water gushes out of the cenotes and into the ocean at high tide, and seawater is drawn back at low tide. Isn't this a bit backward?

GARY SNYDER  
*Kitchener, Ontario*

*You're right—and we're all wet. The article should have stated that cenotes blow out fresh water at low tide; at high tide they suck salt water back into the system.*

### Kinkajous

Back in the September 2002 issue, I read Editor Bill Allen's comment that a magazine like NATIONAL GEOGRAPHIC "can never have too many meerkats." I'd say that when it comes to adorability, the kinkajous I saw in the October 2003 issue run a close second.

BETTY JO OLSON  
*Twin Falls, Idaho*

### Orangutans

Cheryl Knott's article sheds light on the destruction caused by illegal logging and how the overharvesting of tropical timber



**Follow  
the leader.**



destroys the habitat of orangutans in Indonesia. What it fails to mention is the responsibility we as Americans face when we buy a futon or a picture frame at our local retailer. Indonesia and other producer countries would not have such a large illegal logging problem if consumers did not pay high prices for tropical timber products.

VANESSA C. FREY  
*Washington, D.C.*

### **Geographica: Polio's Last Mile**

It was ironic that after I slowly made my way down a cliff with my cane and my NATIONAL GEOGRAPHIC in hand while on vacation in Mexico, the first article I read was about polio. Having contracted the disease 50 years ago as a baby, I think it is important for the world to remember this curse, both for the fact that scourges can be conquered and that complacency about vaccinations is most unwise.

KURT SIPOLSKI  
*Palm Desert, California*

Although much progress has been made in eradicating polio and other diseases, I fear that we will never defeat these age-old enemies until we address their underlying cause—desperate poverty caused by extreme overpopulation. These diseases thrive in areas where there are too many people and not enough resources to support them.

MONIQUE HUENERGARDT  
*Corona, California*

### **Who Knew?**

Joel Achenbach's piece nicely described how genetic engineering can give us insight into the biology of neural development. Unfortunately, in attempting humor, he also undermined the importance of such technology with a lightly mocking tone at the end when describing a genetically engineered mouse. These transgenic mice are not cute parlor tricks; they have proved to be amazingly useful tools in the fields of neuroscience, stem cell biology, cell biology, and immunology.

SUSAN MURRAY  
*Portland, Oregon*

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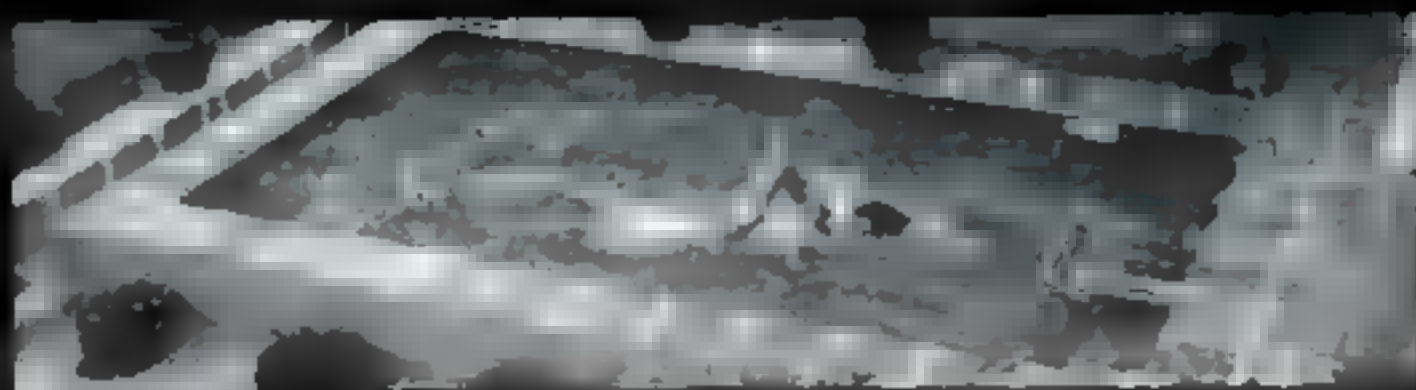


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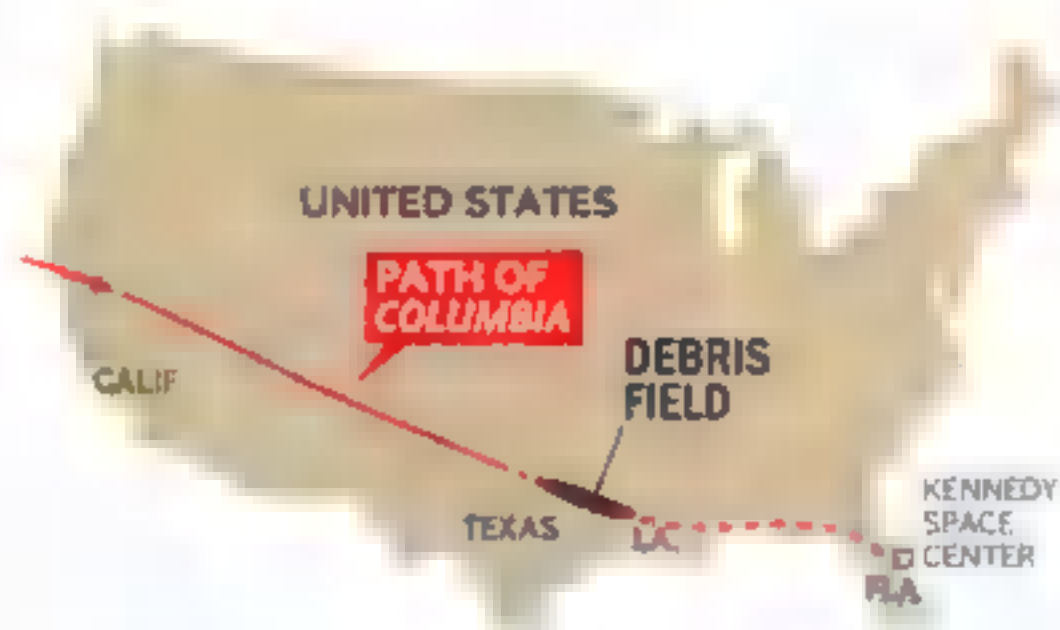
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CARTOGRAPHY

## Trail of Tragedy

*High-tech maps aided shuttle Columbia recovery effort*



On February 1, 2003, Jerry Ross, a senior U.S. astronaut, waited at the end of a runway in Florida to welcome the space shuttle *Columbia* crew back to Earth.

The greeting never happened.

A day later Ross looked out on a sea of grim faces in Lufkin, Texas, a city where pieces of the doomed spacecraft slammed into the ground. The debris field left by the breakup of the shuttle stretched 300 miles (main map).

With an alphabet soup of agencies on hand—among them NASA, FEMA, EPA—Ross, who

would help lead NASA's search effort, feared chaos. But in coordinating the search, NASA and FEMA (the Federal Emergency Management Agency) had a solution to the chaos in the form of another acronym: GIS, geographic information system. Using GIS, mapmakers can add to the grid of a base map various layers of data—like the location of roads, elevations, population densities, or, during the shuttle search, the locations where pieces of wreckage were found. At recovery headquarters in Lufkin, operators used GIS to generate custom maps (Figure 3) to guide the “eyes on the ground”: thousands of Forest Service firefighters walking in lines to spot debris.

“It’s the first time GIS has been the hub of a disaster recovery operation,” says Ron

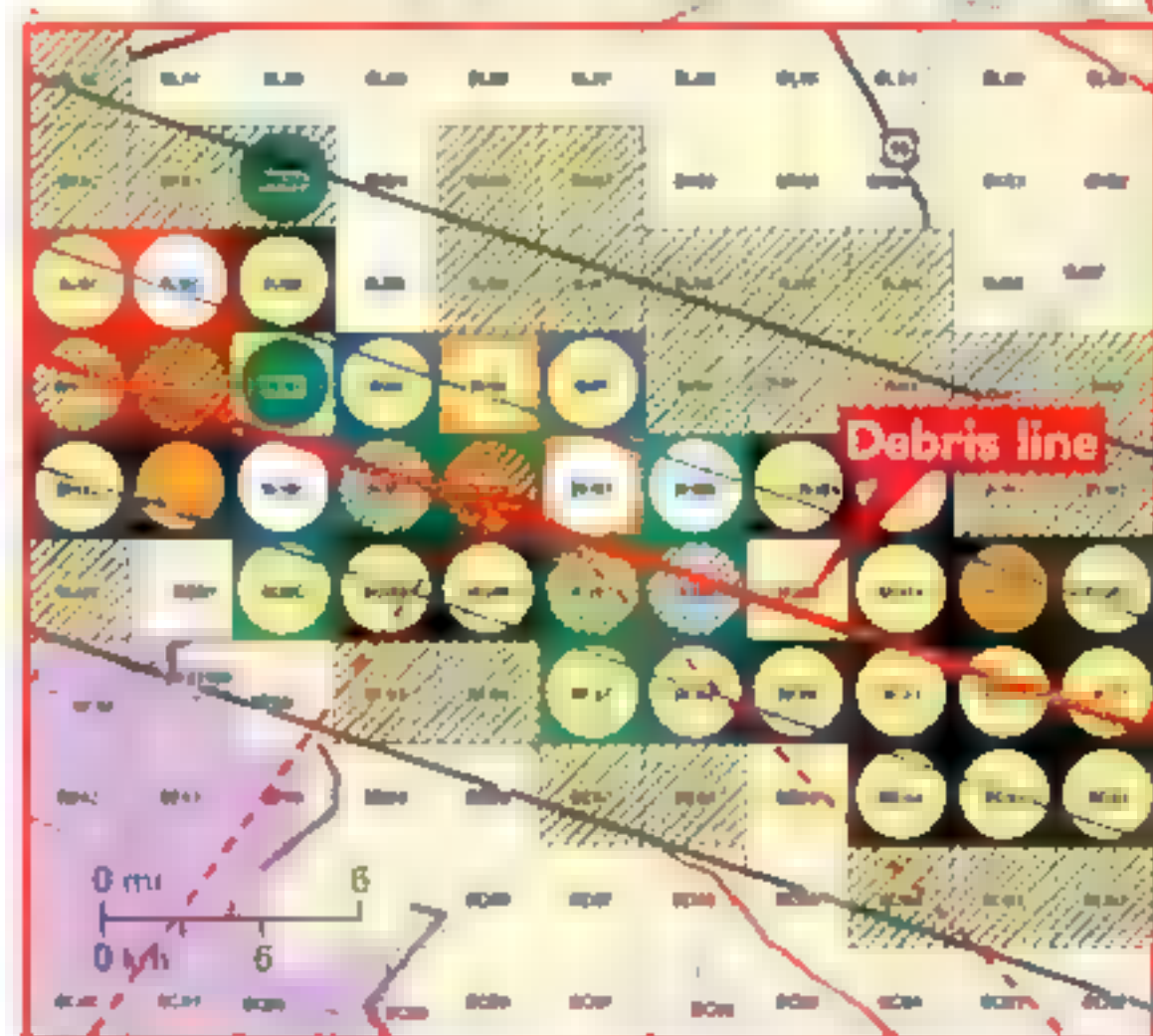


FIGURE 2



FIGURE 3



# A P H I C A

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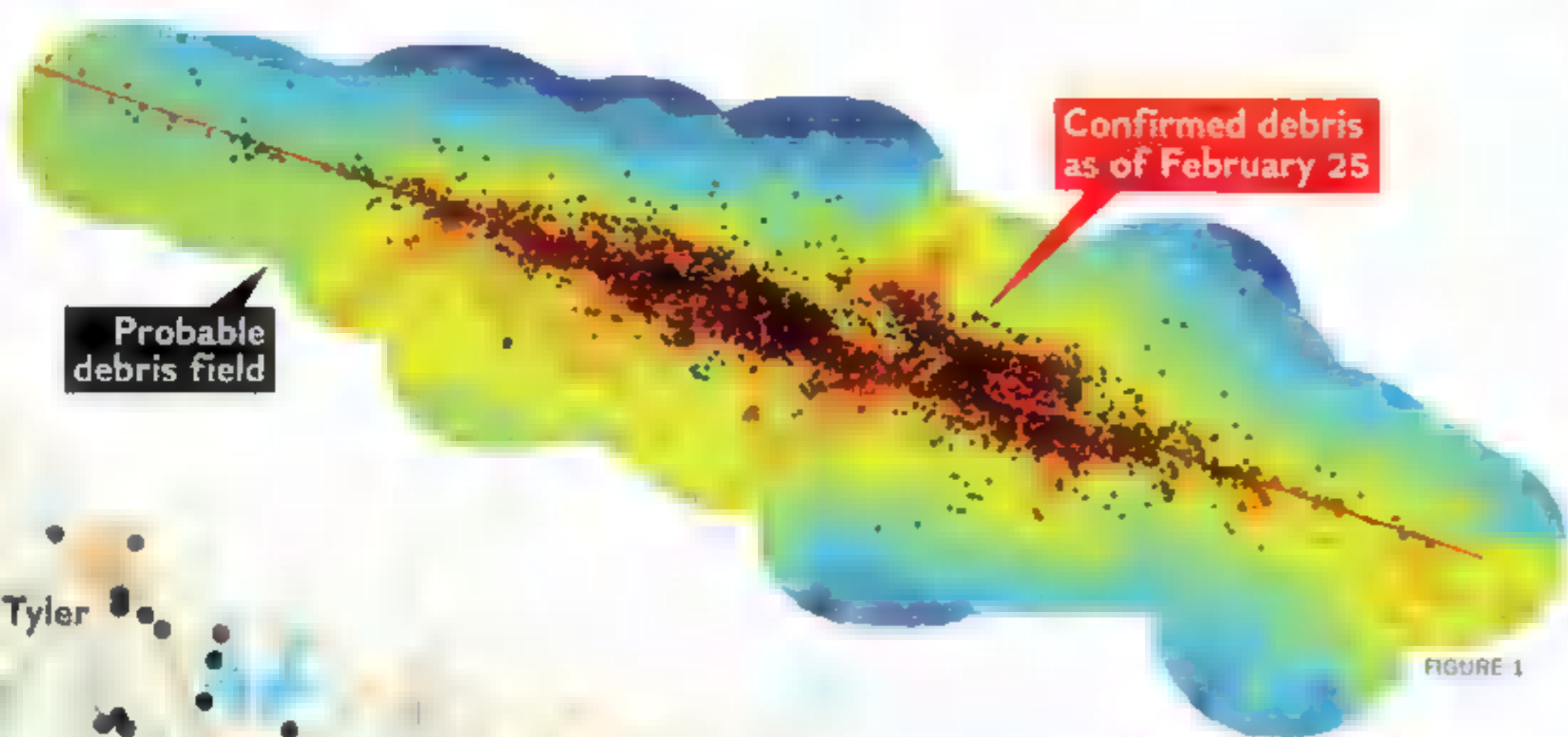
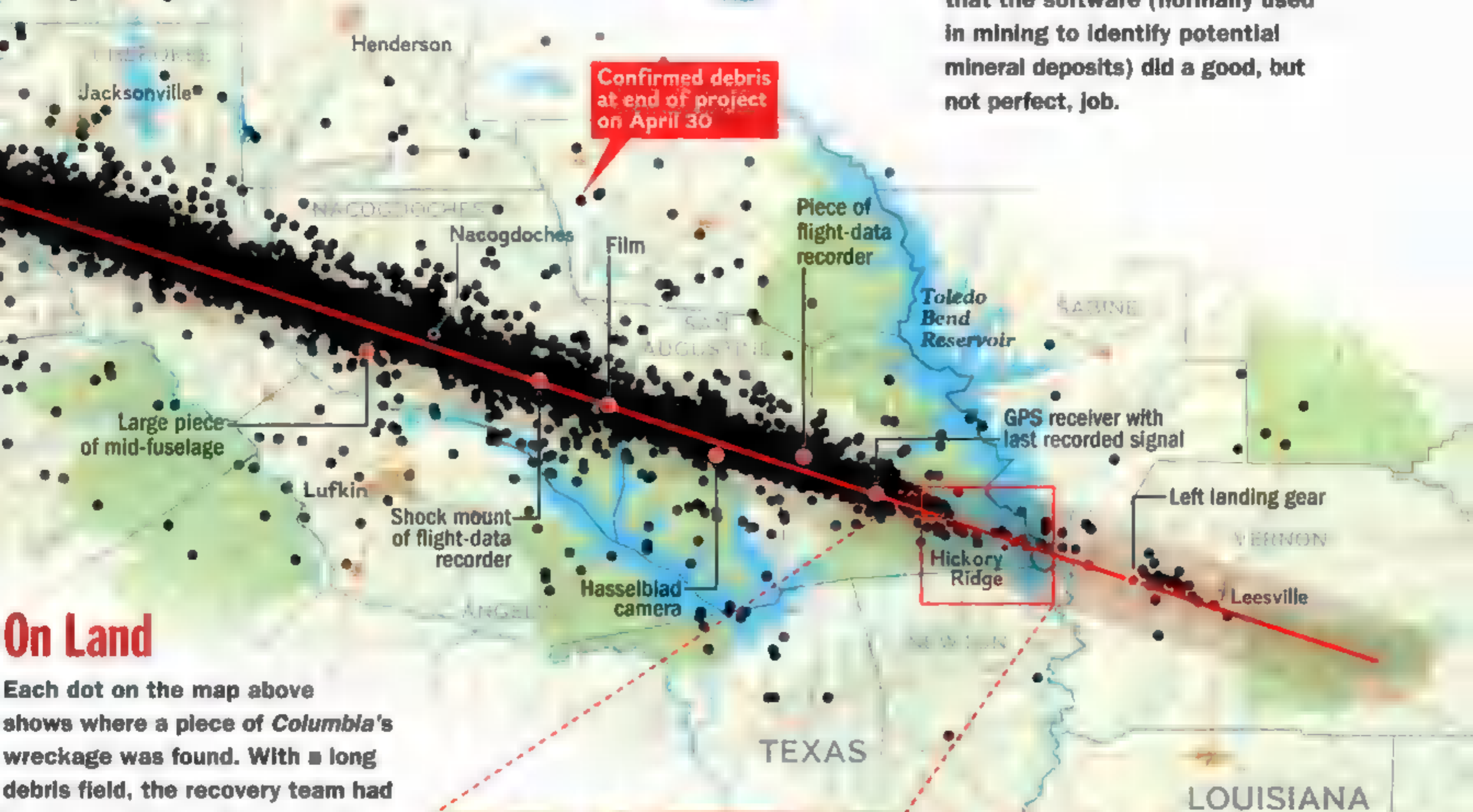


FIGURE 1

## In the Air

Analyzing radar data that had captured the descent of shuttle debris, GIS operators produced a map that showed where pieces were likely to be found (Figure 1). Red and orange indicate areas where debris finds were very likely, yellow, less likely. Blue areas were not worth searching. Black points—confirmed debris—reveal that the software (normally used in mining to identify potential mineral deposits) did a good, but not perfect, job.



## On Land

Each dot on the map above shows where a piece of *Columbia's* wreckage was found. With a long debris field, the recovery team had to move quickly and keep track of everything recovered. Various maps filled the requirements: The massive search area was divided into a grid (Figure 2), with color coding showing how much of every section—each four square nautical miles—had been searched, and whether on foot or by air. Searchers on the ground were given maps (Figure 3) that showed previous debris finds and helped them negotiate rough, often swampy ground.

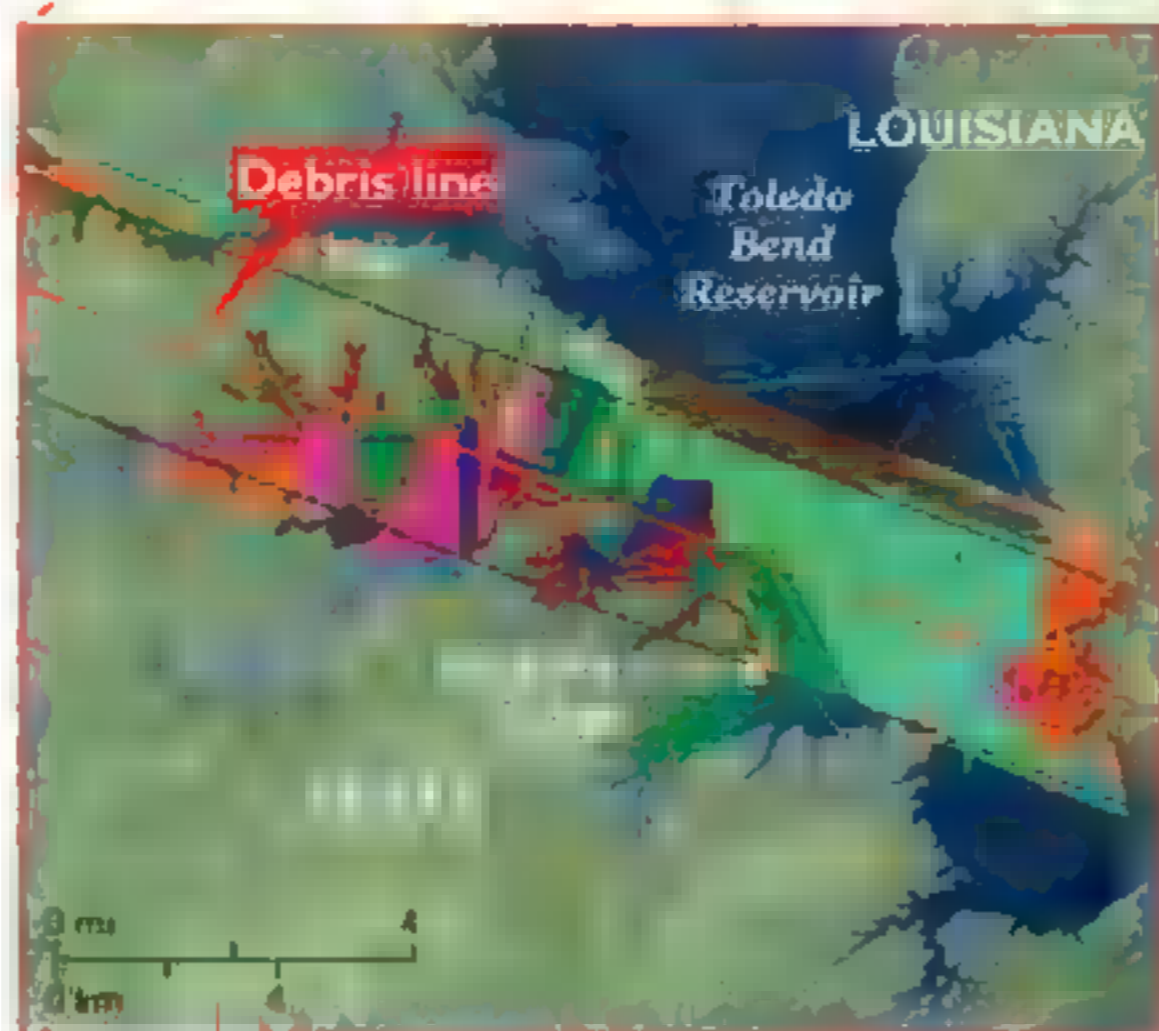


FIGURE 3

## Under Water

Toledo Bend Reservoir (Figure 4) lay in the path of falling wreckage, and an angler actually saw pieces hitting the water. One person guided searchers to a large piece of debris, but a sonar sweep of the lake was a bust—likely because of submerged trees and lake bed rubble. Colors indicate the type of sonar equipment used and the depth of scans.



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Langhelm, GIS database coordinator for the three-month search. "The entire search effort revolved around it."

GIS software did more than generate maps and help direct the search effort—it tracked overall progress (Figure 2) and created computer models, based on radar or other data, predicting where more debris was likely to be discovered (Figure 1).

An array of maps poured out of the GIS area at the Lufkin headquarters. "There were days when we produced over a thousand hard-copy maps on computer printers," says Gerco Hoogeweg of ESRI, one of the companies providing GIS software. Most were field maps to help direct the firefighters, who canvassed a total of 700,000 acres of often treacherous terrain. "The people out walking the ground, finding the wreckage, did an admirable job," Hoogeweg says. "They had to

walk a straight line and if there was a swamp in the way, they just kept going."

The search team recovered nearly 40 percent of *Columbia*, logged the finds in the GIS database, and later took the pieces (above) to the Kennedy Space Center for analysis. None of Jerry Ross's initial fears about the search have come true. Says Ross, "If you'd told me at the beginning of the search that we'd find even 25 percent of *Columbia*, I'd have said you were too optimistic."

Now the optimist is Ross, a seven-time shuttle veteran. With the cause of the crash having been determined and the report issued, Ross is hopeful another shuttle will fly late this year.

—Chris Carroll

**WEBSITE EXCLUSIVE** Find links and resources selected by our Research Division at [nationalgeographic.com/magazine/resources/0402](http://nationalgeographic.com/magazine/resources/0402).



## Final Portrait

Found among the wreckage were 21 rolls of film with recoverable photographs, including the traditional in-flight portrait of the seven astronauts (clockwise, from left): Kalpana Chawla, David M. Brown, William C. McCool, Michael P. Anderson, Ilan Ramon, Laurel Blair Salton Clark, and Rick D. Husband.

NASA/BO114



**EMERGING EXPLORER SPENCER WELLS** By taking blood samples from isolated tribes around the world and analyzing their DNA, geneticist Spencer Wells and his collaborators have discovered that everyone alive today can be traced back to a small tribe of Africans who lived 60,000 years ago. Following this amazing genetic trail, he has charted the ancient journey of these people, continent by continent, as they populated the planet. Part scientist, part detective, Spencer reveals the extraordinary universal link that connects us all.



# Tracing humanity's roots to a single origin

IT HAS BEEN AN AMAZING EXPERIENCE TO WORK TOGETHER WITH THE KALAHARI BUSHMEN, Chukchi reindeer herders, Australian Aborigines, Native Americans, and other indigenous groups throughout the world to discover our shared prehistoric ancestry. These people, with their rich cultural traditions and ancient connections to the land where they live, carry the history of mankind in their blood. When local communities are lost, engulfed by the inexorable tide of assimilation in our increasingly homogenized world, the footprints of our ancestors as they left Africa remain the only link to the past.



Around the World, National Geographic Society has identified Emerging Explorers Program grantees who push the boundaries of discovery.



Mission Programs

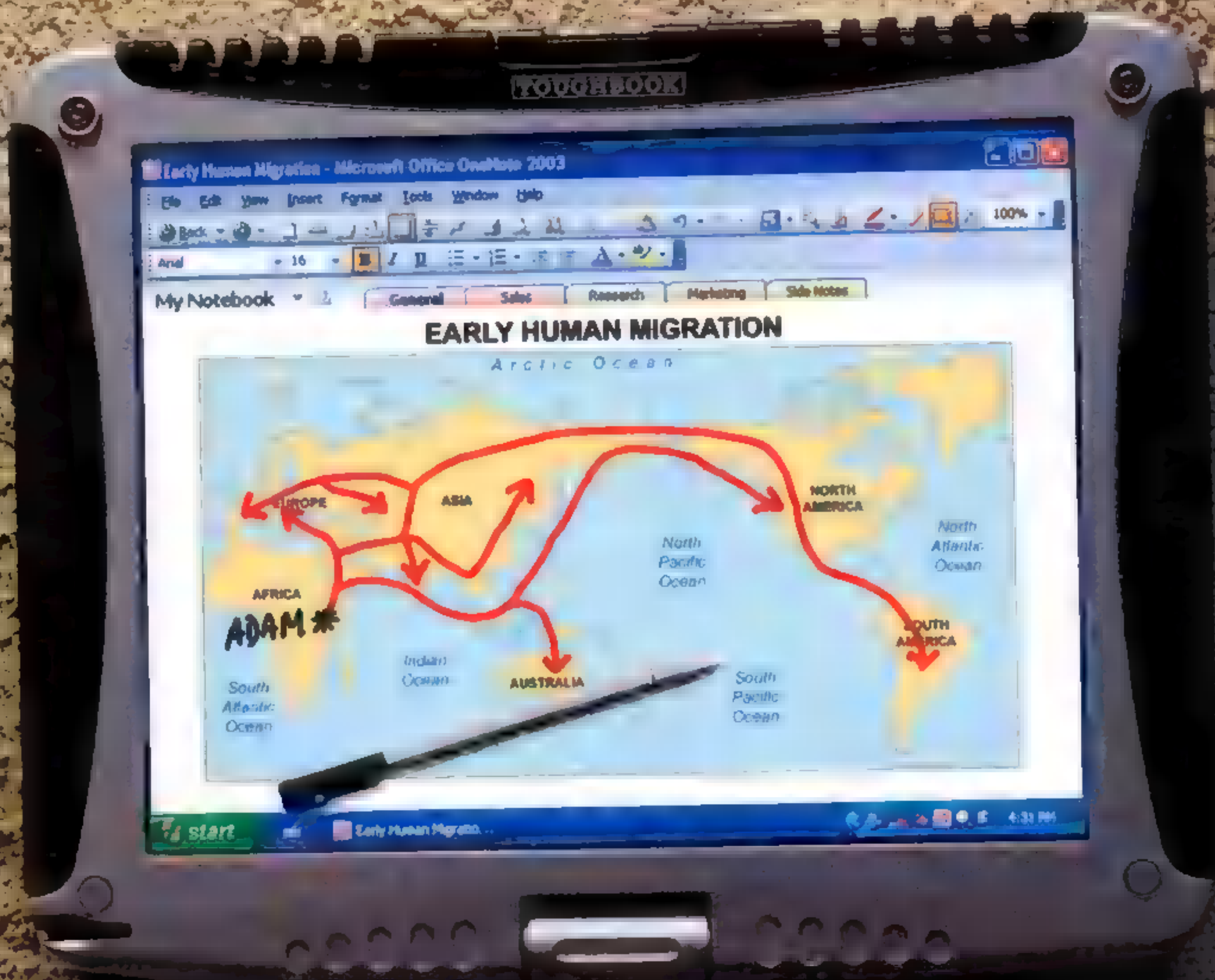
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Your potential. Our passion.

Microsoft recognizes the crucial role technology plays in exploration. Their support of the National Geographic Emerging Explorers Program is helping these new explorers realize their potential.

Photos: Mark Beale





## Technology that goes the distance

For geneticist Spencer Wells, new technology makes it possible to cross time and continents on the DNA trail. The powerful Tablet PC is as simple to use as a pad and pen—allowing scientists and explorers in the field to communicate discoveries and record data with more flexibility and speed than ever before. The Tablet PC puts the full range of Windows XP compatible applications, including Microsoft Office System, at your command anytime, anyplace. To learn more about how far it can take you, visit [Microsoft.com/tabletpc](http://Microsoft.com/tabletpc)







CARDLYN COLE / LOS ANGELES TIMES

After looters left his home last summer, Johnny Thorpe (above) took out a piece of paper he had hidden away. It was a photo of his grandparents, who came to West Africa in 1896 from the U.S. state of Virginia and settled in a Liberian town named—what else?—Virginia. Last July, while Liberians in the capital of Monrovia were laying the bodies of civilians killed in the country's civil war in front of the U.S. Embassy, Thorpe declared, "We are part of them"—meaning Americans. "They should come here now."

In August some 200 U.S. Marines finally did just that—the latest chapter in the complicated story of U.S.–Liberian ties, which began when Americans founded Liberia in 1822. After 47 days the last of the contingent of U.S. peacekeepers was pulled out and helicoptered to ships offshore. While grateful for the U.S. military presence, which helped preserve a fragile cease-fire, Monrovia was saddened by the unannounced departure: They had wanted to hold a ceremony to give the Marines a proper farewell. —Karen E. Lange

## HISTORY

## Born in the U.S.A.

*Liberia, America's West African stepchild*



LIBRARY OF CONGRESS

**1822-24** First African-American immigrants settle at Cape Mesurado, naming it Monrovia (after U.S. President James Monroe) and the colony Liberia—"liberty."

**1847-48** Liberia declares its independence and Americo-Liberian Joseph Jenkins Roberts (right) is elected president.



LIBRARY OF CONGRESS

**1926** Firestone creates world's largest rubber plantation at Harbel, supplying the U.S. auto industry and military.



RONALD REAGAN LIBRARY / HULTON ARCHIVE/GETTY IMAGES

**1989-2003** Rebels led by Charles Taylor, a U.S.-educated Americo-Liberian, invade to topple Doe. In 2003, after Taylor abdicates, the U.S. briefly deploys a small number of Marines in Monrovia as peacekeepers (right).

**1817** American Colonization Society founded to create African homeland for free blacks. The private group sells certificates (left) to raise funds.



LIBRARY OF CONGRESS

**1822-1904** Some 23,000 immigrants (left), mostly from the U.S., arrive to form an Americo-Liberian elite that rules over Liberia's indigenous Africans.



COKER TIRE CO.

**1941-45** During WW II, U.S. uses Liberia as an outpost against the Axis powers in Africa.

**1980s** Americo-Liberian rule ends in a 1980 coup led by Samuel Doe (left, in a 1982 visit to U.S.). In return for Cold War support, U.S. backs Doe's dictatorship.



ISSOUF SANOGO, STAFF/GETTY IMAGES



## GEOPHYSICS

## Gravity's Rainbow

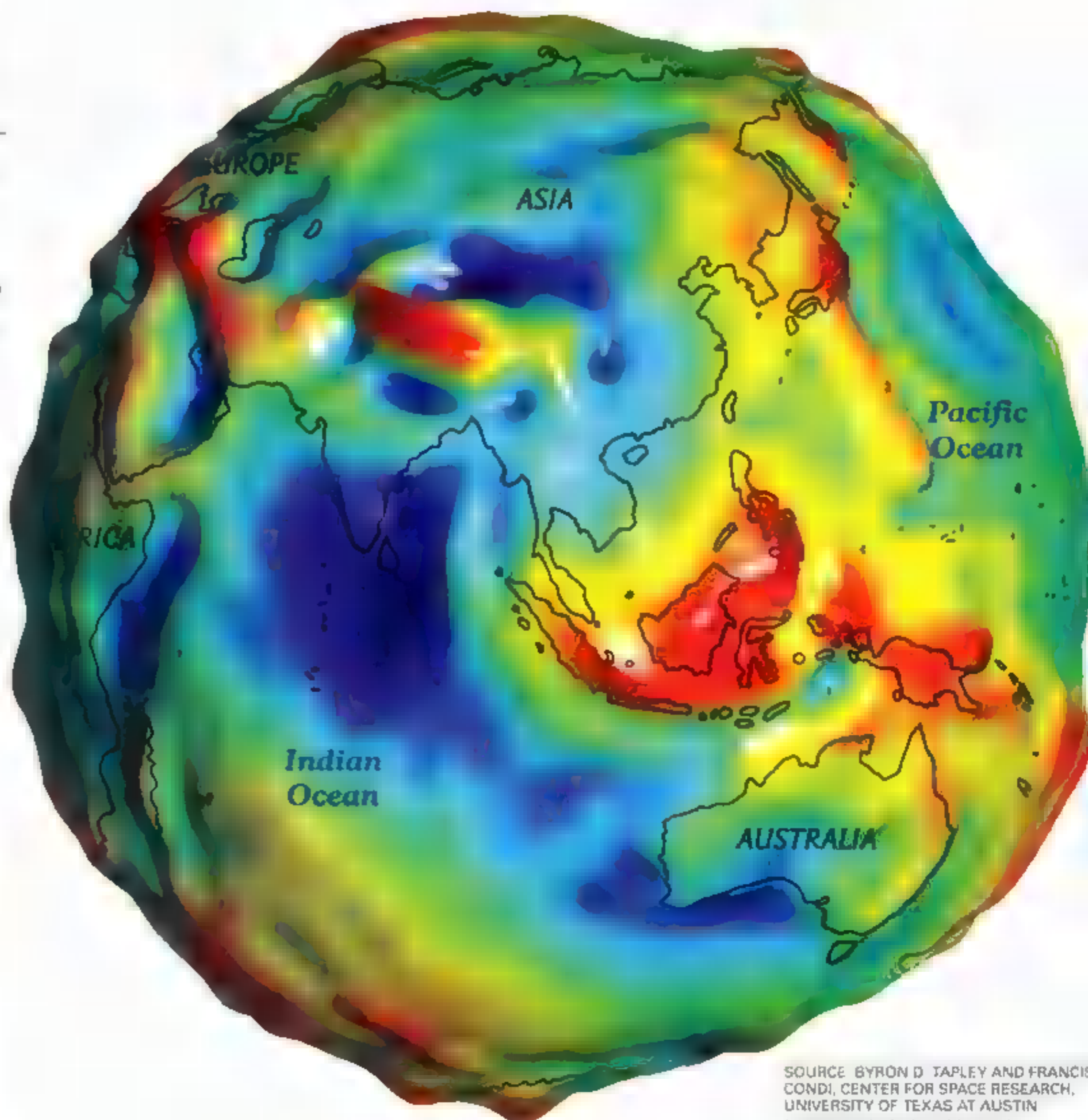
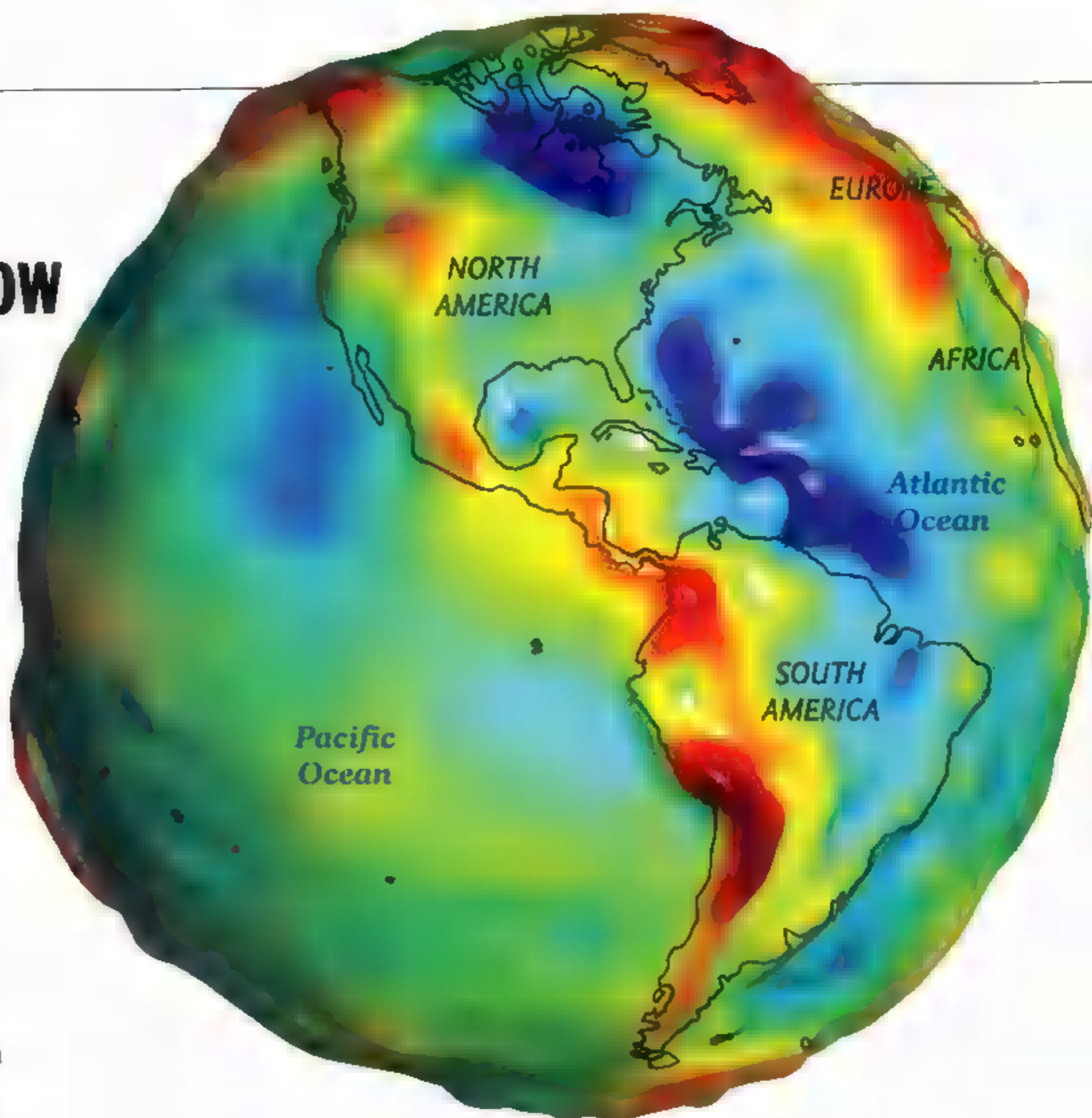
*Mapping places with pull*

**W**inds gust, tides ebb, but gravity, we presume, doesn't change. Yet scientists have long known that very heavy masses—mountain ranges, polar ice caps, atmospheric and ocean currents—generate slight gravitational tugs. Now a pair of recently launched satellites—part of a joint U.S.-German project called GRACE (Gravity Recovery and Climate Experiment)—are mapping gravity's fluctuations. "While you can make surface measurements with gravimeters," says Byron Tapley, GRACE's director, "only satellites can measure the whole Earth each month."

So how does GRACE work? Normally the twin satellites, positioned 137 miles apart, move in lockstep. But varying gravitational pull from features below makes the lead satellite speed up or slow down. Onboard sensors record the rate and duration of acceleration caused by these gravitational ripples, and GPS receivers plot the location where it happens. Stitch the data together and you get a map of Earth's ever changing gravitational field. Features at or below the surface create visible anomalies; those due to colliding tectonic plates are some of the most intense.

Surveying thousand-mile swaths of the planet at a time, GRACE will allow scientists to track polar ice melt and spot aquifers. "Eventually," says Tapley, "we will be able to let countries in Africa know how their aquifers are changing."

—Michael Behar



SOURCE: BYRON D. TAPLEY AND FRANCIS CONDI, CENTER FOR SPACE RESEARCH, UNIVERSITY OF TEXAS AT AUSTIN; NATIONAL GEOGRAPHIC MAPS

Gravity scale







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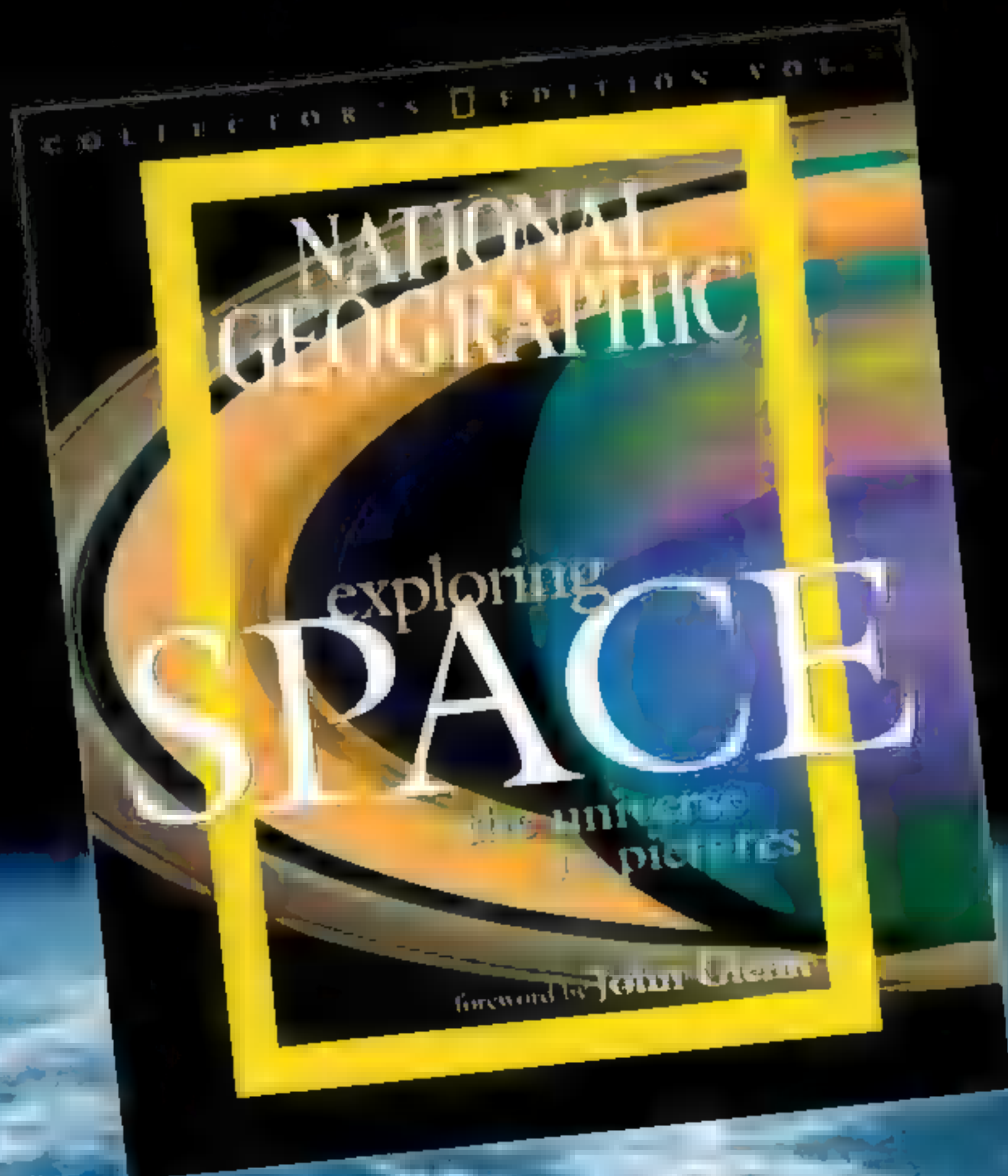








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COVER: ERICH KARKOSCHKA, UNIVERSITY OF ARIZONA; NASA/STSCI.



# My Seven



## World's Deepest Caves

**Bill Stone** *Cave explorer and engineer*

This month Bill Stone will be deep below Mexico's Sierra Juarez, on an expedition that could move Cueva Cheve to the top of this rapidly changing list. In the past decade Stone has pioneered the use of advanced diving technology in deep caves—a revolution that is getting cavers through flooded caverns once considered impassable, fueling what Stone calls “an international race toward the center of the Earth.”

**1 Krubera (Voronja), republic of Georgia, 5,610 feet** (2001 expedition) “Ukrainian and Russian cavers [right] think a new route may soon get them even deeper,” says Stone.

**2 Lamprochtsofen, Austria, 5,354 feet** (1998) Explored from bottom up (main entry is at base of mountain).

**3 Gouffre Miroida, France, 5,335 feet** (2003) A team claims to have reached 5,686 feet, but “a French commission suspects a survey error,” says Stone.

**4 Reseau Jean Bernard, France, 5,256 feet** (1990) Has held record for deepest known cave six times.

**5 Torca del Cerro, Spain, 5,213 feet** (1998) One of few caves with two routes deeper than 3,280 feet.

**6 Sarma, Georgia, 5,062 feet** (2003) “Exploration here and in Krubera cave was delayed by civil war in the 1990s,” says Stone.

**7 Cehl 2, Slovenia, 5,030 feet** (2003) The deepest of five deep caves in Kanin Mountain on Slovenia's border with Italy.

BILL STONE (TOP), AL WARILO

### WEBSITE EXCLUSIVE

Find out if Bill Stone and his teammates on the Cueva Cheve expedition become first to go deeper than 6,000 feet at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).



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# Do It Yourself

**POLAR BEARS** (SEE PAGE 30)



**GO THERE**

## Polar Bears, Up Close and Personal

Photographer Norbert Rosing has had his share of unpleasantly close encounters with polar bears. His tips for avoiding danger in bear country:

PAUL NICKLEN

### PICKS

## 3 lessons

Photographer **Norbert Rosing** has had his share of unpleasantly close encounters with polar bears. His tips for avoiding danger in bear country:

- **Keep your distance.** Stay as far from bears as you can—and don't let being in a car or a truck give you a false sense of security. A bear once destroyed a tire on Norbert's pickup truck with one bite. He managed to drive away on a flat tire.
- **Never let bears smell your food.** Taking a break in a car, a friend of Norbert's once accidentally left a window open a crack. When he poured water on his instant soup, a bear smelled it, ran over, and smashed the window.
- **Never go out alone.**

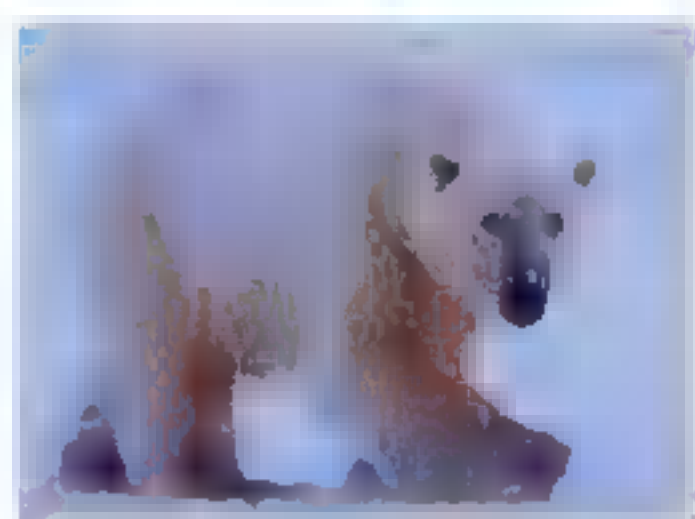
A mistake Norbert won't repeat. While he was out alone bear-watching, his truck got stuck in a snow drift. As he frantically tried to shovel himself out, two bears—hidden among the drifts—lumbered toward him. He dug his truck out just in time.

**WEBSITE EXCLUSIVE**  
Watch photographer Norbert Rosing's video of sparring bears at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).

**TRY IT AT HOME**

## Follow That Bear

Like scientists who work with polar bears in the field, armchair



GEORG BANGJORD

researchers can track radio-collared bears on their home computers. A website sponsored by the wildlife group WWF in partnership with the Norwegian Polar Institute tracks the bears' movements as well as changes in the sea ice that the animals rely on to travel and hunt. (Ice breakup has happened earlier on average in recent years.)

Two females named Lena (below left) and Yana have been wearing transmitters since August 2002. Signals from the bears are beamed to a satellite, and their locations are then posted on the website. Go to [panda.org/polarbears](http://panda.org/polarbears) to follow Yana and Lena as they roam near the Norwegian island of Spitsbergen, where they raise their cubs.



“The clams were the only ones  
that benefited from my arthritis.  
Sorry guys, I’m back.”



**VIOXX PROVIDES POWERFUL 24-HOUR RELIEF OF ARTHRITIS.**

▼ The less pain you feel, the more everyday victories you can achieve. And VIOXX may help. VIOXX is a prescription medicine for the relief of arthritis pain and stiffness.

**ONE PILL FOR ALL DAY, ALL NIGHT RELIEF.**

Just one little pill can relieve your pain and stiffness all day and all night for a full 24 hours.

**VIOXX TARGETS A KEY SOURCE OF PAIN.**

VIOXX specifically targets only the COX-2 enzyme, which is a key source of pain and inflammation. In clinical studies, once-daily VIOXX effectively reduced pain and stiffness.

**TAKE WITH OR WITHOUT FOOD.**

You don't have to worry about scheduling VIOXX around meals.

**VIOXX IS NOT A NARCOTIC.**

**FIND OUT IF VIOXX CAN MAKE A DIFFERENCE IN YOUR LIFE.**

Ask your doctor or healthcare professional about VIOXX today. Call 1-800-MERCK-30 for your free information guide on VIOXX, or visit [vioxx.com](http://vioxx.com).

**IMPORTANT INFORMATION ABOUT VIOXX.**

People with allergic reactions, such as asthma, to aspirin or other arthritis medicines should not take VIOXX. In rare cases, serious stomach problems, such as bleeding, can occur without warning.

Tell your doctor if you have liver or kidney disease, or a history of angina, heart attack, or a blocked artery in your heart. VIOXX cannot take the place of aspirin for the prevention of heart attack or stroke. VIOXX should not be used by women in late pregnancy.

In clinical studies, commonly reported side effects included upper respiratory infection, diarrhea, nausea, and high blood pressure. Report any unusual symptoms to your doctor.

Please see the Patient Product Information for VIOXX on the next page for additional information that should be discussed with your doctor.

**ONCE DAILY**  
**VIOXX**<sup>®</sup>  
**(rofecoxib)**

**FOR EVERYDAY VICTORIES**



**Patient Information about**  
**VIOXX® (rofecoxib tablets and oral suspension)**  
**VIOXX® (pronounced "VI-ox")**  
**for Osteoarthritis, Rheumatoid Arthritis and Pain**  
**Generic name: rofecoxib ("ro-fa-COX-ib")**

You should read this information before you start taking VIOXX®. Also, read the leaflet each time you refill your prescription, in case any information has changed. This leaflet provides only a summary of certain information about VIOXX. Your doctor or pharmacist can give you an additional leaflet that is written for health professionals that contains more complete information. This leaflet does not take the place of careful discussions with your doctor. You and your doctor should discuss VIOXX when you start taking your medicine and at regular checkups.

#### What is VIOXX?

VIOXX is a nonsteroidal anti-inflammatory drug (NSAID) that is used to reduce pain and inflammation (swelling and soreness). VIOXX is available as a tablet or a liquid that you take by mouth.

VIOXX is a medicine for:

- relief of osteoarthritis (the arthritis caused by age-related "wear and tear" on bones and joints)
- relief of rheumatoid arthritis in adults
- management of acute pain in adults (like the short-term pain you can get after a dental or surgical operation)
- treatment of menstrual pain (pain during women's monthly periods).

#### Who should not take VIOXX?

Do not take VIOXX if you:

- have had an allergic reaction such as asthma attacks, hives, or swelling of the throat and face to aspirin or other NSAIDs (for example, ibuprofen and naproxen).
- have had an allergic reaction to rofecoxib, which is the active ingredient of VIOXX, or to any of its inactive ingredients. (See Inactive Ingredients at the end of this leaflet.)

#### What should I tell my doctor before and during treatment with VIOXX?

Tell your doctor if you are:

- pregnant or plan to become pregnant. VIOXX should not be used in late pregnancy because it may harm the fetus.
- breast-feeding or plan to breast-feed. It is not known whether VIOXX is passed through to human breast milk and what its effects could be on a nursing child.

Tell your doctor if you have:

- history of angina, heart attack or a blocked artery in your heart
- kidney disease
- liver disease
- heart failure
- high blood pressure
- had an allergic reaction to aspirin or other NSAIDs
- had a serious stomach problem in the past.

Tell your doctor about:

- any other medical problems or allergies you have now or have had.
- all medicines that you are taking or plan to take, even those you can get without a prescription.

Tell your doctor if you develop:

- serious stomach problems such as ulcer or bleeding symptoms (for instance, stomach burning or black stools, which are signs of possible stomach bleeding).
- unexplained weight gain or swelling of the feet and/or legs.
- skin rash or allergic reactions. If you have a severe allergic reaction, get medical help right away.

#### How should I take VIOXX?

VIOXX should be taken once a day. Your doctor will decide what dose of VIOXX you should take and how long you should take it. You may take VIOXX with or without food.

#### Can I take VIOXX with other medicines?

Tell your doctor about all of the other medicines you are taking or plan to take while you are on VIOXX, even other medicines that you can get without a prescription. Your doctor may want to check that your medicines are working properly together if you are taking other medicines such as:

- warfarin (a blood thinner)
- theophylline (a medicine used to treat asthma)
- rifampin (an antibiotic)
- ACE inhibitors (medicines used for high blood pressure and heart failure)
- lithium (a medicine used to treat a certain type of depression).

VIOXX cannot take the place of aspirin for prevention of heart attack or stroke. If you take both aspirin and VIOXX, you may have a greater chance of serious stomach problems than if you take VIOXX alone. If you are currently taking aspirin for prevention of heart attack or stroke, you should not discontinue taking aspirin without consulting your doctor.

#### What are the possible side effects of VIOXX?

Serious but rare side effects that have been reported in patients taking VIOXX and/or related medicines have included:

- Serious stomach problems, such as stomach and intestinal bleeding, can occur with or without warning symptoms. These problems, if severe, could lead to hospitalization or death. Although this happens rarely, you should watch for signs that you may have this serious side effect and tell your doctor right away.
- Heart attacks and similar serious events have been reported in patients taking VIOXX.
- Serious allergic reactions including swelling of the face, lips, tongue, and/or throat which may cause difficulty breathing or swallowing and wheezing occur rarely but may require treatment right away. Severe skin reactions have also been reported.
- Serious kidney problems occur rarely, including acute kidney failure and worsening of chronic kidney failure.
- Severe liver problems, including hepatitis, jaundice and liver failure, occur rarely in patients taking NSAIDs, including VIOXX. Tell your doctor if you develop symptoms of liver problems. These include nausea, tiredness, itching, tenderness in the right upper abdomen, and flu-like symptoms.

In addition, the following side effects have been reported: anxiety, blurred vision, colitis, confusion, decreased levels of sodium in the blood, depression, fluid in the lungs, hair loss, hallucinations, increased levels of potassium in the blood, insomnia, low blood cell counts, menstrual disorder, palpitations, pancreatitis, ringing in the ears, severe increase in blood pressure, tingling sensation, unusual headache with stiff neck (aseptic meningitis), vertigo, worsening of epilepsy.

More common, but less serious side effects reported with VIOXX have included the following:

Upper and/or lower respiratory infection and/or inflammation  
 Headache  
 Dizziness  
 Diarrhea  
 Nausea and/or vomiting  
 Heartburn, stomach pain and upset  
 Swelling of the legs and/or feet  
 High blood pressure  
 Back pain  
 Tiredness  
 Urinary tract infection.

These side effects were reported in at least 2% of osteoarthritis patients receiving daily doses of VIOXX 12.5 mg to 25 mg in clinical studies.

The side effects described above do not include all of the side effects reported with VIOXX. Do not rely on this leaflet alone for information about side effects. Your doctor or pharmacist can discuss with you a more complete list of side effects. Any time you have a medical problem you think may be related to VIOXX, talk to your doctor.

#### What else can I do to help manage my arthritis pain?

Talk to your doctor about:

- Exercise
- Controlling your weight
- Hot and cold treatments
- Using support devices.

#### What else should I know about VIOXX?

This leaflet provides a summary of certain information about VIOXX. If you have any questions or concerns about VIOXX, osteoarthritis, rheumatoid arthritis or pain, talk to your health professional. Your pharmacist can give you an additional leaflet that is written for health professionals.

Do not share VIOXX with anyone else; it was prescribed only for you. It should be taken only for the condition for which it was prescribed.

Keep VIOXX and all medicines out of the reach of children.

Inactive Ingredients:

Oral suspension: citric acid (monohydrate), sodium citrate (dihydrate), sorbitol solution, strawberry flavor, xanthan gum, sodium methylparaben, sodium propylparaben.

Tablets: croscarmellose sodium, hydroxypropyl cellulose, lactose, magnesium stearate, microcrystalline cellulose, and yellow ferric oxide.

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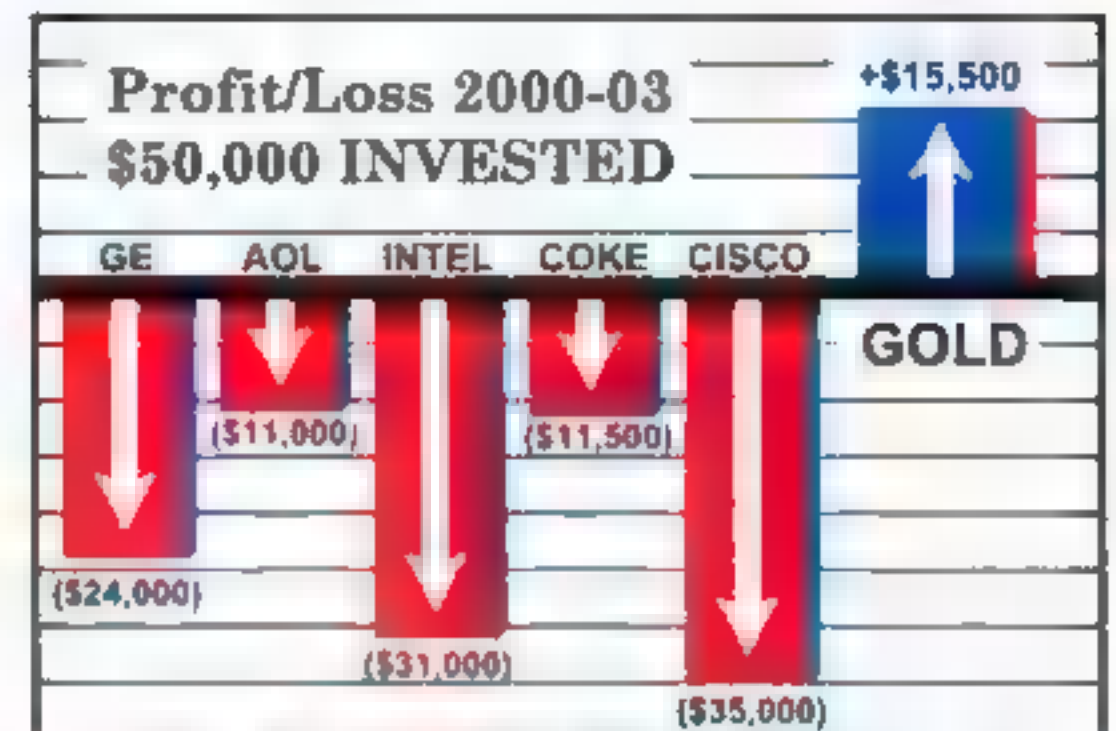
By executive order of Ronald Reagan and Congress Public Law 99-185, Americans can now buy new Government Issued Gold. Where once restricted as a nation, Ronald Reagan opened the doors for everyone to purchase Gold and create security within their financial portfolios. In today's volatile economic environment it is very important for all Americans to own Gold. The Gold Eagles' design features a moving tribute to the unity of the American family, in which a male eagle, soars above a female eagle that is nesting with her newborns. Thank you to Ronald Reagan, one of the greatest presidents of all time, for the Gold American Eagle program.

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# Behind the SCENES

AT THE NATIONAL GEOGRAPHIC SOCIETY



NGS PHOTOGRAPHER JODI COBB

## Readers Hear Silenced Voices

*Articles on slavery and Untouchables prompt action*

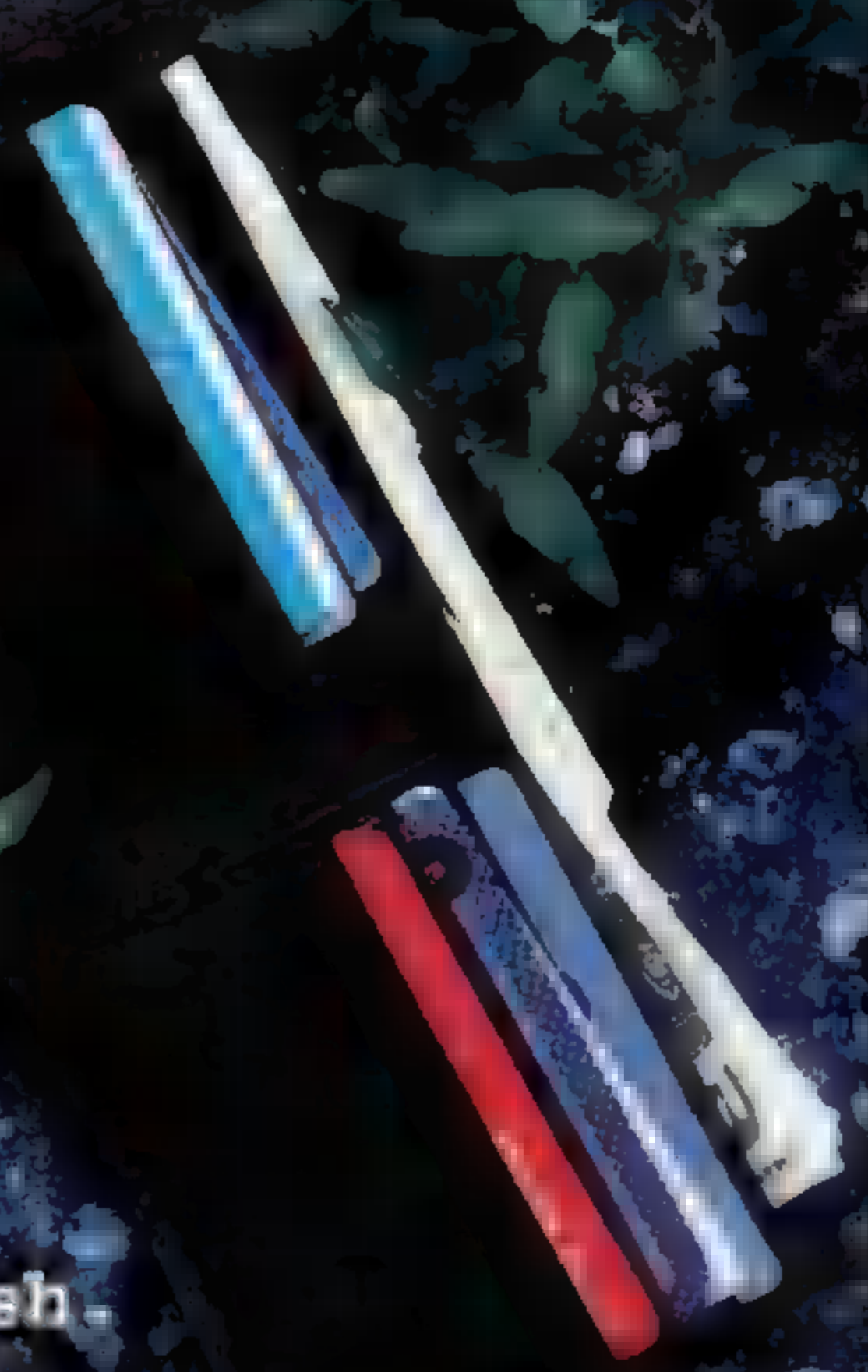
Two recent stories in the magazine dealt with lives most readers could hardly imagine: those of India's Untouchables (June 2003) and of modern-day slaves (above, September 2003). Response to both stories was overwhelming. The slavery package generated more than ten times the number of reader letters we typically receive on an article, many of them asking to help. In the U.S. Congress, Rep. Frank Wolf, co-chairman of the human rights caucus, distributed copies of the article to fellow members of Congress, administration officials, and diplomats. In Rome, city officials

who read the article were so moved that they're planning a conference on slavery. (For a list of human rights organizations, go to [nationalgeographic.com/magazine/archives](http://nationalgeographic.com/magazine/archives).)

The article on Untouchables also spurred people to action. One reader inquired about adopting an Untouchable child. Others expressed interest in helping two Untouchable men who had been disfigured by acid. And Columbia University graduate student Corey Washington created the website [untouchables.org](http://untouchables.org) in the hope that it will help make Untouchables "into the apartheid issue of this generation."







- Keep the wallet. Keep the cash.**
- Return the wallet. Keep the cash.**
- Return both. Keep your self-respect.**

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# Worlds Apart

*Families coming together*



JEFF HUTCHENS/NGC

Ten-year-old Josh Noble (above, left) admits he wasn't thrilled about participating in *Worlds Apart*, the National Geographic Channel series (Saturdays at 8 p.m. ET/PT) that sends American families off to live like locals in far-flung places. Josh thought that the

experience would be like *Survivor*, where "the people look like they're starving." But when his mother, Debbie, told him the whole family would be disqualified if he didn't go, he complied.

When the Nobles first arrived in Mongolia, where they would spend ten days living like nomads, Debbie loved it. But she began to have doubts when Josh and his sister, Jasmine, 8, got sick. "I thought, What have I gotten us into? We've never even camped."

The kids recovered, and the family stuck it out. Debbie found that she and her husband had the same concerns as Mongolian parents—"educating our kids, keeping them safe, giving them more opportunities than we had." The Nobles also learned some new skills: wood chopping, shepherding, and horseback riding. And Josh made a new

friend, Avirjin (left, at right). "He taught me to do chores like a Mongolian boy," says Josh. "Now I'd like him to come to America, so I can show him my life."

## What we learned on our family vacation

**More valuable lessons learned by American families sent to live in Kenya, Mongolia, and Papua New Guinea for *Worlds Apart*: Yak milking takes skill.**

**Raw cabbage** lasts a long time, even when left unrefrigerated.

**Rocks** make good toys.

**Thornbushes** make good racks for drying clothes.

**Sleeping**, when you're in the desert, is better under the stars than in a grass hut.

**Women** shoulder the brunt of work in many rural societies.

## The Really, Really Big Picture

Our recent special issues have covered everything from ancient Egypt to swimsuits. This time we wanted to go, well, further—and farther. With help from NASA, we've assembled a portfolio of images that includes colliding galaxies, blazing comets, Martian mysteries, and inspiring views of our own planet from space.

But while heavenly bodies are

the stars of this show, the issue also covers the early space program. One photo shows a young John Glenn shaving before his historic trip into orbit in 1962.

"I was just concentrating on not cutting myself," Glenn writes in his introduction to the issue. "That would have been a lousy start to what I hoped was going to be a great day."

*Exploring Space* will be available at newsstands, bookstores, and online at [nationalgeographic.com/magazine](http://nationalgeographic.com/magazine) on February 1.



### GET MORE

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NATIONAL GEOGRAPHIC

### CARBON CYCLE (PAGE 88)

■ **Forces of Change: A New View of Nature** Twenty thinkers—from John McPhee to David Quammen—present a new vision of the world, stressing the interrelatedness of all natural phenomena. The book includes discussions of global warming and the carbon cycle (\$40.00).

■ **EarthPulse Online** Explore National Geographic's online home for conservation. Go to [nationalgeographic.com/earthpulse](http://nationalgeographic.com/earthpulse) and follow dozens of links to websites with detailed information on climate, oceans, wild species, and much more.

■ **Cyclone! Video** Continued climate change may increase the intensity of dramatic weather events. View footage of some of the world's most shocking storms (\$19.95).



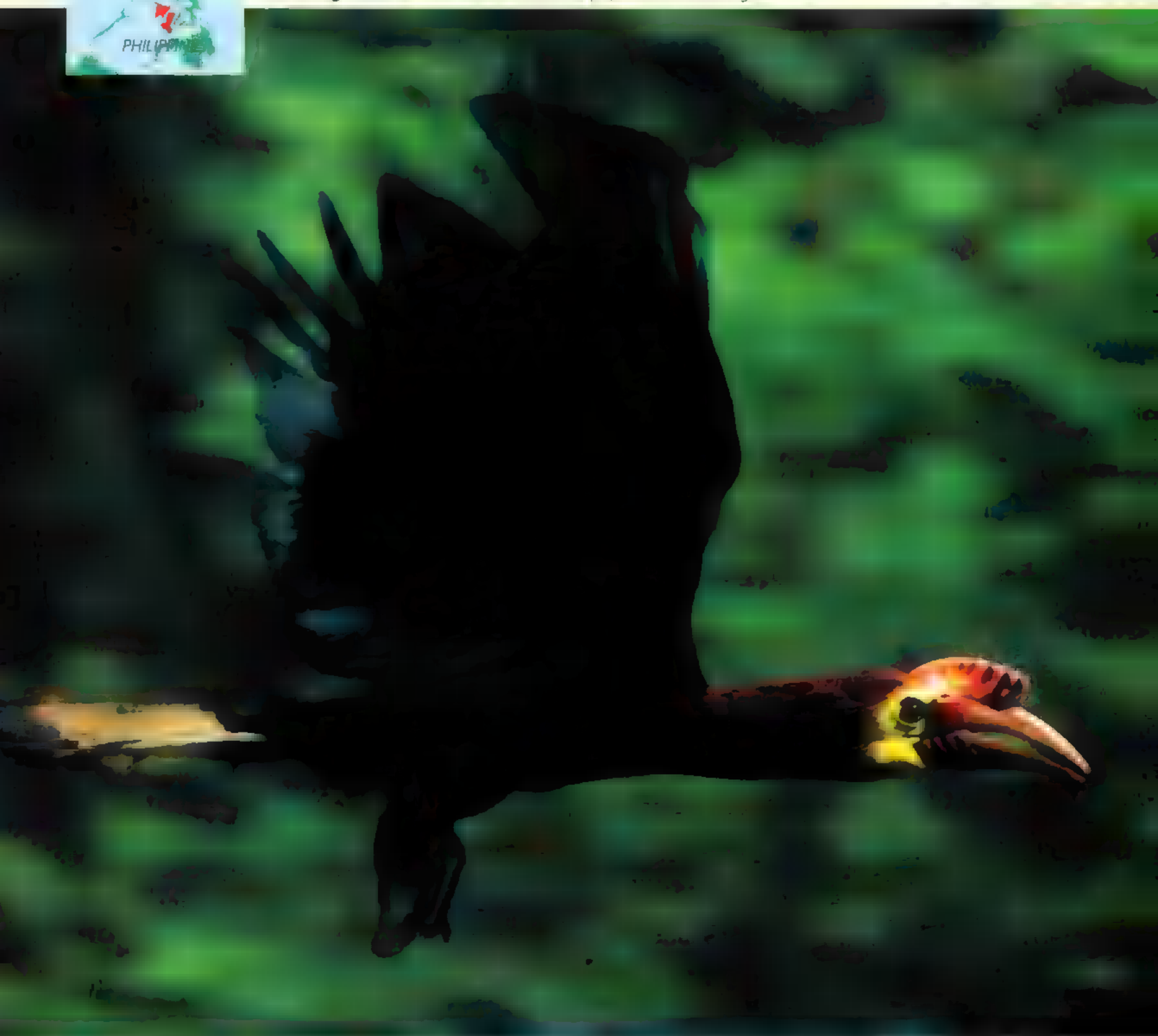


**Visayan Wrinkled Hornbill (*Aceros waldeni*)**

**Size:** Length, 60-65 cm **Weight:** Males, 1,100-1,200 g; females, 700-800 g

**Habitat:** Presumed extinct on Guimaras, it now survives only on the Western Visayas islands of Negros and Panay

**Surviving number:** Estimated at 120-160; populations declining



*Photographed by Timothy Lohmann*

# WILDLIFE AS CANON SEES IT

Charisma can be a curse. Look at the Visayan wrinkled hornbill, whose enormous red bill, ringing calls and resplendent coloring seem designed to draw attention. It has to go to great lengths for privacy. When the female is ready to lay eggs, she and her mate use mud to wall her into their tree-hole nest. There she stays until the nestlings are ready to fly, utterly dependent on the male for food; if he runs into trouble, the whole family

perishes. And troubles have multiplied in recent years, most notably hunting and the wholesale destruction of its primary forest habitat. As a result, this distinctive bird may one day be conspicuous only by its absence.

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# Who Knew?

## CHEMICAL ECOLOGY

### Plants on the Warpath

*The roots of combat*

At some point in the 1970s, people started talking to houseplants. They figured plants would grow better if made the recipients of verbal nourishment and a little extra CO<sub>2</sub>. There was an even bigger presumption: Plants were gentle, peace-loving, tolerant organisms. (Hippies, obviously.)

But now we know the sordid truth: Some plants are stone-cold killers.

Consider the spotted knapweed, accursed invader of the American West. The dogma among ecologists is that invasive alien species thrive because they're free of the diseases, insects, and other enemies that keep them in check on their native turf.

Knapweed, however, has a secret weapon: Its roots secrete a chemical that kills other plants. This is known as allelopathy, and it's tough to prove because soil is such a dense stew of microbes, mites, nematodes, and all sorts of chemicals.

How do you tweeze a toxin from the mix and know where it came from and what it's doing?

Colorado State University scientists recently managed to identify knapweed's killer chemical.

They grew the plant in a sterile liquid, then examined the compounds its roots released into the liquid. When one chemical, catechin,

was applied to the roots of other plants, it triggered the production of free radicals, which passed from the roots upward, activating a wave of cell death. In essence, a tiny amount of catechin induced other plants to commit suicide.

"People think plants are innocuous. We're showing that plants can be as mean as any animal," says Jorge Vivanco, leader of the team.

Plants may also use chemicals to "communicate" with one another. In the case of knapweed, the message is simple: "You die now." (Vivanco's group calls this "negative communication." To say the least.) But sometimes the message, delivered to fellow members of the species, is something along the lines of "mites attacking; shore up your defenses."

For example, when lima bean plants are attacked by spider mites, they call out the cavalry, emitting a chemical distress signal that attracts carnivorous mites that eat the spider mites. The signal inspires nearby uninfested lima bean plants to do the same thing.

Because we humans are so biased toward visual and auditory signals, and don't tend to sniff everything and lick random objects, we don't realize how much the world around us is shot through with chemical warnings.

Plants don't make that mistake. When something crosses them, they take action.

So the next time you take a stroll in a garden, maybe you should be looking over your shoulder.

—Joel Achenbach

WASHINGTON POST STAFF WRITER

## IT MATTERS

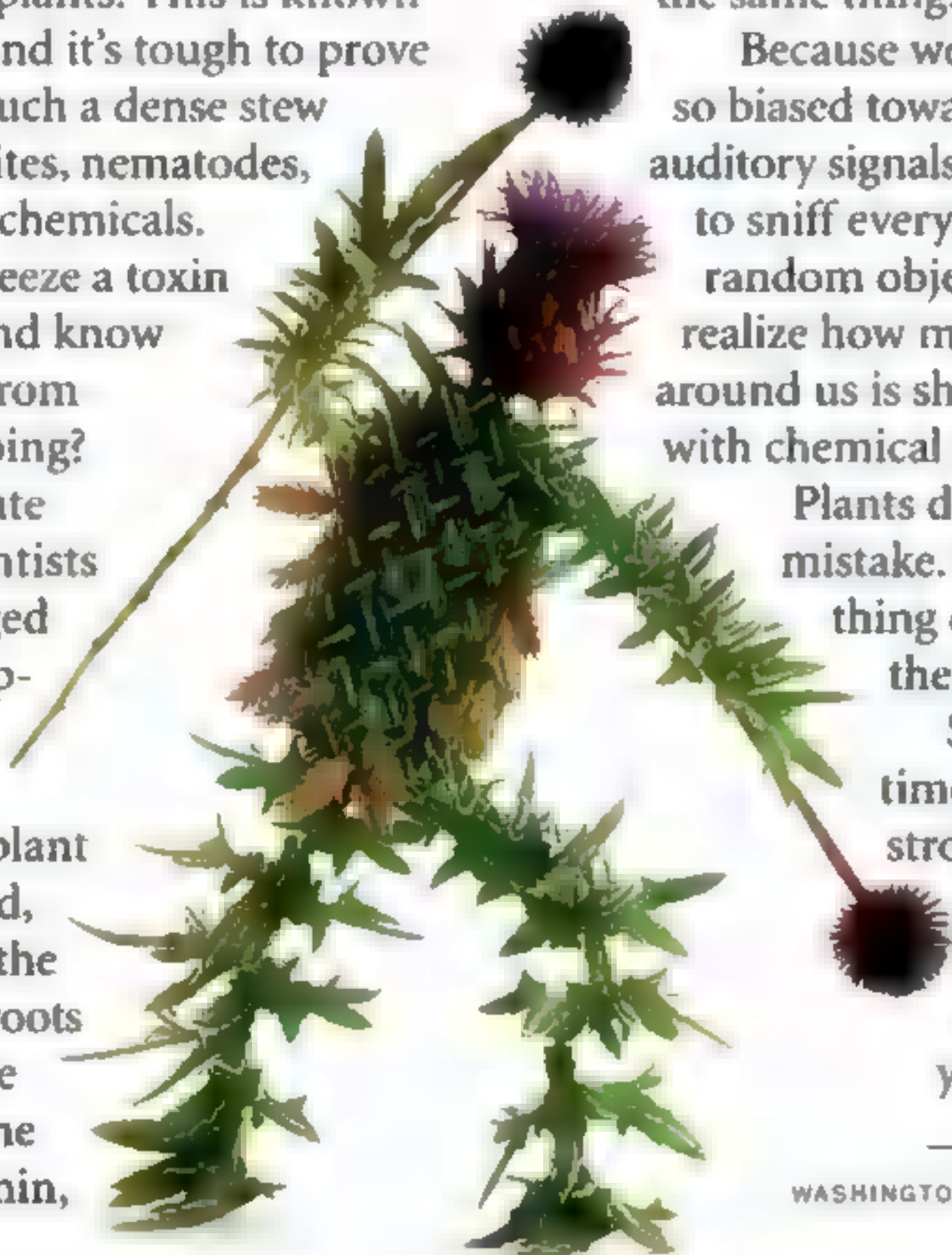
**When plants send chemical messages to other organisms, they may be advertising for pollinators.**

Wafting fragrances are come-hither chemical lures used by plants so they can procreate. Along with blossom colors and shapes, scents attract the bees, wasps, flies, butterflies, beetles, moths, birds, bats—even some mice and lizards—that make it possible for 90 percent of the flowering plants on Earth to reproduce. Pollinators matter. For every dollar a Quebec apple farmer invests in honeybees to service an orchard, crop value goes up by \$185. North Dakota sunflower farmers get more and better seeds from flowers that get a lot of buzz. From fruits to nuts, a big chunk of the human diet depends on the connection between flowers and pollen movers.

—Lynne Warren

## WEBSITE EXCLUSIVE

For more about chemicals and plants, and for links to Joel Achenbach's work, go to resources at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).





# HAN

THE DYNASTY AROSE 2,200 YEARS AGO AND LASTED MORE THAN FOUR CENTURIES. TODAY, ETHNIC CHINESE STILL CALL THEMSELVES HAN—AN ECHO OF A GOLDEN AGE IN ART, POLITICS, AND TECHNOLOGY WHEN CHINA RIVALED THE ROMAN EMPIRE IN POWER AND PRESTIGE.

BY MIKE EDWARDS  
PHOTOGRAPHS BY LOUIS MAZZATENTA

A gilded bronze horse, thought to be a gift from Emperor Wu to his sister, reflects the prosperity of a mighty dynasty. Valued for practical and ritual reasons, horses carried the Han Empire to Central Asia and inspired the belief that they could take the emperor to heaven.

BRONZE HORSE, MUSEUM OF HAN, SHANGHAI PROVINCE; HEIGHT 34 INCHES









**CONTINUING A HAN TRADITION**, a Chinese fortune-teller near Luoyang sees the future in the lines of a palm. With an eye toward profit, modern soothsayers tend to give good news, buoyed by an increasingly open political climate.







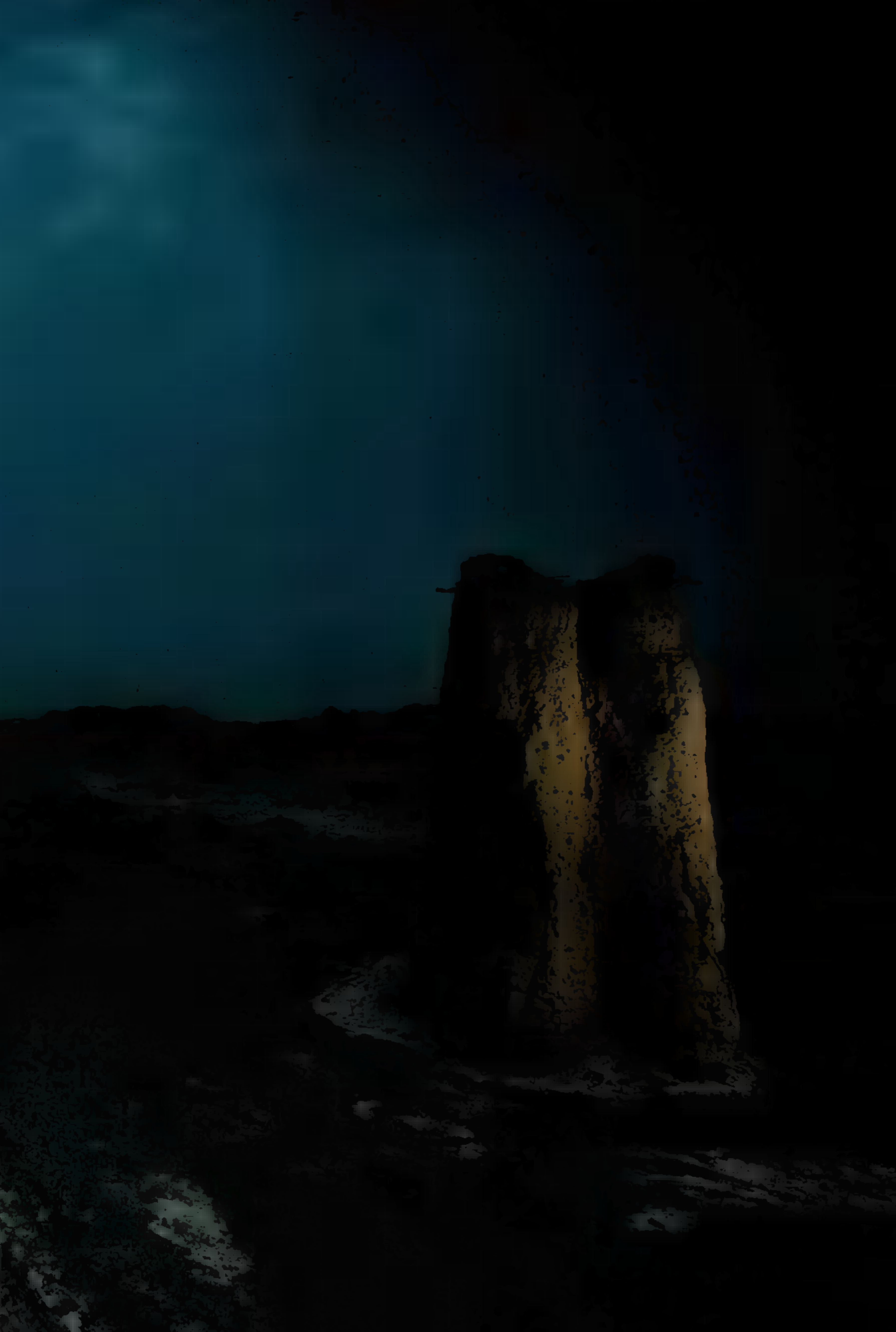
**U**nder a spreading paulownia tree the village smithy stands, pounding red-hot iron. As his hammer strikes again and again, what was a plain slab of metal begins to look like a hoe. Not your sissy flower-garden hoe but a heavy, wide, thick-bladed brute instrument, a hoe for the ages. "You can't break them," a villager says of the hoes made by Liu Shiwa. "I've been using one for 12 years."

In the village of Shijiawan, near the ancient city of Luoyang in east-central China, the smith is a treasured citizen. Village farm plots, lush with cabbages and onions, owe their furrows and friable soil to hoes and rakes produced on the forge in front of Liu Shiwa's house. Two pigs grunt in a pen in a corner of his yard. Chickens and a dog wander about.

It's a scene straight out of the Han dynasty. Historians say the Han era ended 18 centuries ago. They err. That pig sty, the chickens, the dog are just like the miniature ceramic farmstead bric-a-brac that Han folk placed in the tombs of the departed, symbolic sustenance for the afterlife. Forge and hoe clinch the ancient tableau, an advanced iron working was a Han hallmark.

**RUIN WITH A VIEW** The remains of a 45-foot-tall watchtower in Xinjiang command a critical westward vista on the edge of the Han Empire. The soldiers who manned the lookout, largest in a chain of earthen towers, sent up smoke signals at the first sign of marauders.









Another hallmark of the Han: durability. Among the longest of China's major dynasties, it survived, with minor interruption, for more than four centuries. From its founding in 206 B.C. the Han state was as powerful and prestigious in East Asia as the Roman Empire, its approximate contemporary, was in the West. Like Rome, it expanded into "barbarian" territory on its flanks, particularly to the northwest, where its armies cleared the way for trade along the Silk Road. And, like Rome, the dynasty spawned its share of weak rulers and sloughed into turmoil before collapsing, in A.D. 220.

Still, it bequeathed a template of ideal rule—

a united China and a self-perpetuating government—that became the goal of all subsequent dynasties, just as it is for the dynasty (officially communist, but with capitalism busting out all over) that holds power in China today. In the Han legacy, too, are spiritual and ethical dynamics that guide millions of Asians. One is Confucianism, based on the moral values of Confucius, which became official ideology of the Han court (not that the Han rulers were always moral). Even the name Han, which the first emperor adopted from a river, endures. It's what ethnic Chinese call themselves: *Han ren*, Han people.





**I**n many fields Han workers were far ahead of their Roman counterparts. They employed the wheelbarrow and the pulley to move goods, the water-powered trip-hammer to pulverize grain and ores, and the bellows to pump air into furnaces. When an emperor went out in his carriage, he rode in the shade of a regal parasol that—unique in its time—could be collapsed, thanks to sliding metal ribs. And the Han were the first to make a commodity that revolutionized learning, which they called *zhi*. We call it paper.

A eunuch, Cai Lun, told Emperor He about making *zhi* in A.D. 105. Perhaps Cai Lun used

**HANDS CLASPED** in greeting, Zhang Qian, emissary of Wu Di (“martial emperor”), returns on horseback to the Western Han capital of Changan, part of today’s city of Xian. In the late second century B.C., Emperor Wu sent Zhang Qian on epic journeys westward along the Silk Road to forge diplomatic and military ties and to bolster Han power in Central Asia. Envoys of the Wusun, a nomadic people northeast of the Fergana Valley, follow Zhang Qian to offer their prized horses to the emperor, who was enchanted by them. The animals’ speed, strength, and size earned them the name “heavenly horses.”





**EVIDENCE** that the Han and Romans were linked in trade, a Caucasian face appears on a wool weaving from the first or second century A.D., discovered in a grave on the Silk Road in Xinjiang. Stitched into a pair of pants, the piece, woven in a style not used by the Han, likely came from the West via Central Asian traders.

ROBERT CLARK, XINJIANG  
MUSEUM, URMUMU







methods similar to those I saw at a paper mill south of Nanjing. Two men dipped a screen into a vat of pulp made of inner tree bark and rice straw, which looked like watery oatmeal. They raised a layer of dripping slush and examined it carefully. It had to be smooth, not too thick, not too thin. Pressed and dried, it became a sheet of high-quality calligrapher's paper.

Only a few paper fragments bearing writing have been found in Han tombs. For all we know, the Han used paper mostly to wrap fish. Yet they were writing like mad: poetry, complex mathematical problems, history, a huge dictionary, government reports, and the world's earliest surviving large-scale census (57,671,400 people in A.D. 2). They wrote with brushes and lampblack ink on wooden tablets or slips of bamboo, and also on silk. Tens of thousands of these documents have survived, delivering to scholars a portrait of life two millennia ago.

For example, we know from a cache of legal documents retrieved in Hubei Province that the traditional Chinese respect for the elderly was sternly enforced. "The law said that a wife who beat a grandfather or grandmother was to be 'cast away into the marketplace,' which meant being chopped to death," said Robin D. S. Yates, a scholar at McGill University in Montreal, who has studied the Hubei bamboo slips. Even slander of older persons was a capital offense. Note, however, that a scolding wife could be beaten by her husband, and it would not be considered a crime.

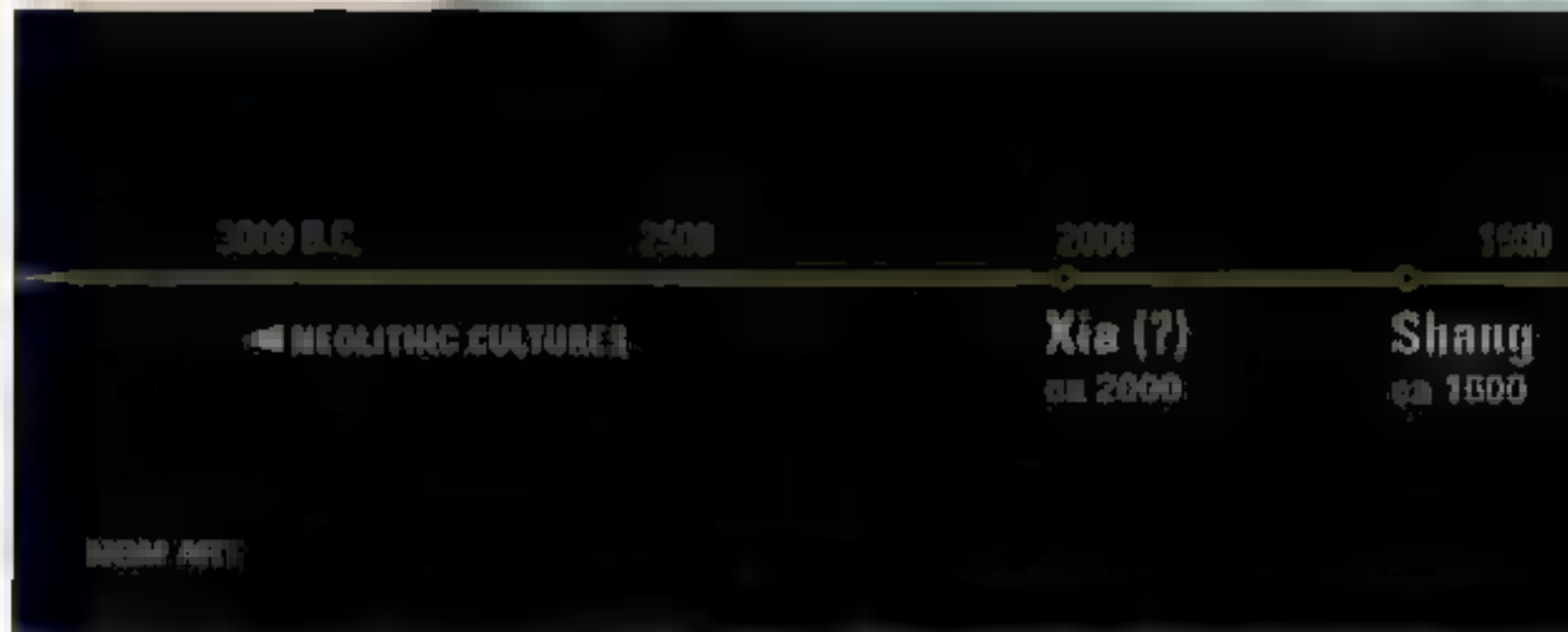
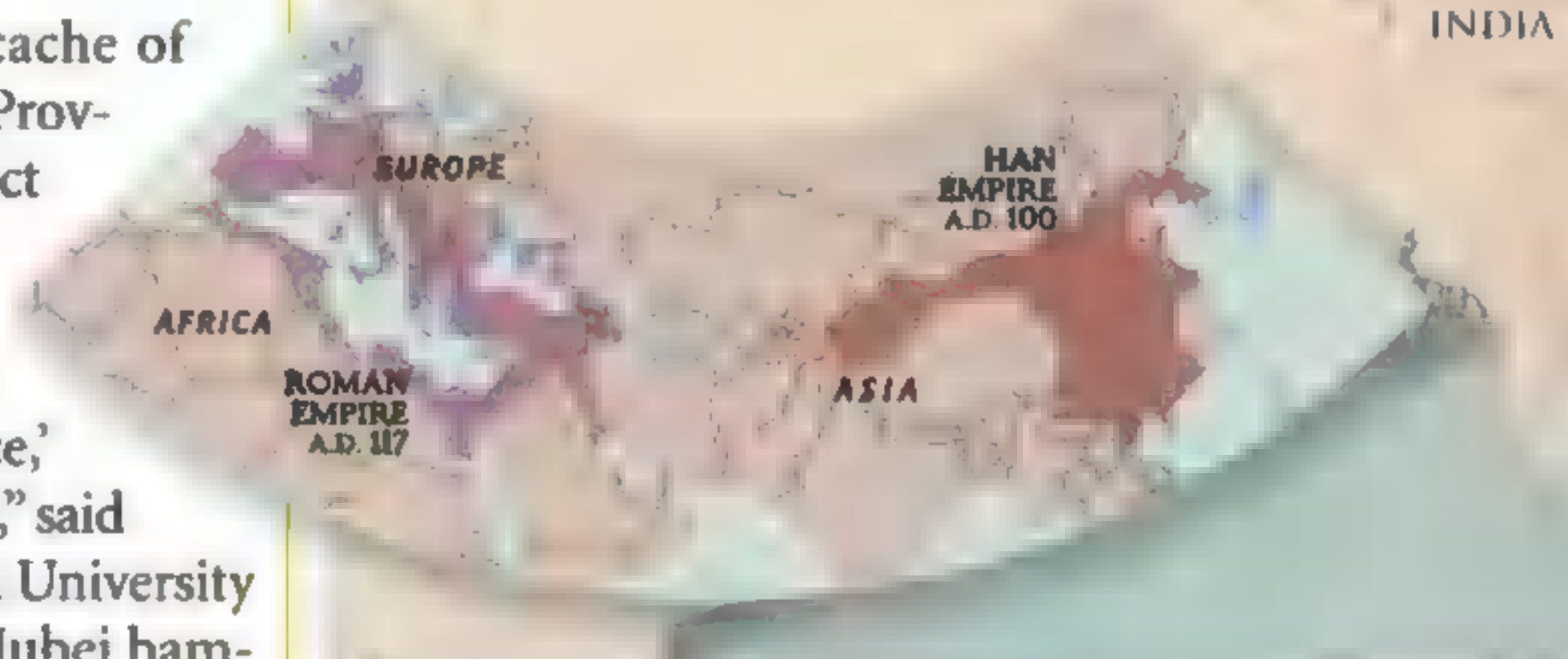
**A**t last the whole world is mine," the first Han emperor, Liu Bang, is said to have declared as he claimed the imperial throne in 202 B.C., the first of 27 Lius to reign. Far from the whole world, his writ extended across a territory only about half as large as today's China. Tough, and common as his surname—China swarms with people named Liu—he despised learned Confucians, whom he readily identified by their distinctive peaked hats. According to an incident recounted by a famous Han historian, Sima Qian, when Liu Bang encountered one of these worthies he "immediately snatches the hat from the visitor's head and pisses in it."

Liu Bang had been a minor official in the previous dynasty, the Qin (or Chin, from which "China" derives). The Qin was the first dynasty



## A TALE OF TWO POWERS

At its greatest extent around A.D. 100, the Han Empire's reach was comparable to Rome's (inset). Military threats led to Han expansion in the deserts of the northwest, the Korean Peninsula, and Southeast Asia. Trade followed the military occupation. The styles of empire were markedly different: Rome's economy relied on slavery, for instance, while Han prosperity rode mainly on the backs of free peasants.



to weld China's oft-warring kingdoms into a single state. It was also cruel and soon collapsed. With the throne up for grabs, Liu Bang raised an army. His most formidable opponent, a general named Xiang Yu, captured Liu Bang's father and sent Liu Bang an ultimatum: "Surrender or I will boil your venerable sire alive!"

Liu Bang replied merely: "Send me a cup of the soup."

Bravado won out; Dad wasn't stewed, and Liu Bang finally crushed Xiang Yu, who then, to deal with the humiliation, committed suicide with his one remaining concubine.

The victor put his capital in the city of





Changan (“eternal peace”), whose ruins lie today in the suburbs of its bustling, tourist-packed successor, Xian (“western peace”). In those ruins on a June afternoon, I stood atop a mound 50 feet high—the site of Liu Bang’s palace. Portions of Changan’s city wall, which encompassed 13 square miles, poked from fields where peasants were reaping wheat, some with scythes, some at the wheels of combines.

Liu Bang, also known as Gaozu, “high ancestor,” (symbolic names were often posthumously conferred on emperors) called his palace Lasting Joy. Joy? I thought I heard screams from the ruins. After his death in 195 B.C. his empress, Lu

Zhi, tried to hijack the empire for her own family. She had several Liu Bang sons born to concubines murdered and for good measure mutilated his favorite mistress and had her tossed into a privy. Routing other Liu kin and loyal generals from their fiefdoms—the spoils of rulership—she replaced them with her own relatives. Fifteen years passed before the Liu clan managed to regain control, enthroning a surviving Liu Bang son, Emperor Wen. The Lius then wiped out all the empress’s kin they could get their hands on.

Oh, the Han women! This wouldn’t be the last time an empress or concubine colluded in a dangerous political game.





**UNEARTHED** from tombs of nobility, relics (left to right) reveal Han attitudes toward life and death. The stone carving of a man battling a bear symbolizes the human struggle with nature. A gilded silkworm that promises fine clothing after death reflects the importance of Han women, whose silk weavings were vital to the economy. An incense burner held by an immortal atop a dragon signals good wishes for the deceased, while a horned, tongue-wagging face in terra-cotta served to ward off evil from homes and tombs. Bronze objects carried from life into death included a spearhead hung with figurines of prisoners and a girl with a lamp that would illuminate the next world.

**E**mperor Wen, historians have written, won popular support by abolishing the gruesome punishments that the Han had copied from the Qin dynasty, such as severing the left foot of a man who forced a woman to become his wife. But from his study of Han laws, Yates doubts that Wen was so magnanimous. “What I see is that he got rid of some minor punishments,” he said, “but not the terrible mutilations, such as cutting off the nose.”

Some scholars at the Han court attempted to explain all events by an inevitable cycle of *yin*, dark and cold, and *yang*, light and warm. In their emperors they surely saw both. When the historian Sima Qian offended emperor Number 5, Wu Di, by daring to stand up for a disgraced general, Wu Di punished him by castration. (Sima Qian continued to write his history, perhaps the most important of all Han texts.)

Wu Di (“martial emperor”) was a lad of 15 in 141 B.C. when he began a reign that lasted 54 years, one of the longest in Chinese history. His inaugural was a *yang* time; the empire was stable, granaries and the treasury were overflowing, and, as Sima Qian wrote, “every family had enough to get along on.” On the south side of Changan, Wu Di built an academy devoted

to the works of Kongfuzi, Master Kong, as Chinese call Confucius. The sage had long been dead, but disciples—those erudite men scorned by Liu Bang—had preserved his teachings. The academy trained

administrators for Wu Di’s government, paving the way for Confucianism to become the court’s dominant ideology.

Confucians believed an emperor ruled by a mandate from heaven and that his virtue should inspire good behavior in his subjects. They prized honor, learning, and order, and sought to uphold authority. In the course of Han reign, thousands of academy alumni spread Confucian ethics across the empire, from whence the philosophy traveled to most of East Asia.

Wu Di paid respect to his ancestors and to heaven and sometimes sought out fortune-telling Daoists. Daoism in Wu Di’s time was a philosophy evolving into a religion. Its fundamental tenet was to let things be, an avoidance of mankind’s quest for power and wealth and an acceptance of whatever will happen. But some Daoists claimed to be able to read the future.

And some claim that talent now. So, seeking my own fortune, I headed to the Daoist temple complex of Lou Guan Tai (“high view”) on a mountainside a couple of hours east of Xian. “We





had important roles in every dynasty because we prognosticated according to the stars,” said a priest I met there. He had a round face and wore his hair balled atop his head. “This is the way we do it now,” he added, displaying a box of a hundred varnished bamboo slivers. “Take one,” he invited. I did.

“Number 64,” he read from the stick. He disappeared and returned with a slip of yellow paper, also numbered 64, and pronounced: “Everything you are doing is in harmony with the heavens. All the people you will meet in China are good.”

My interpreter, Gao Jian, drew a stick and also received a happy prognosis. Hmm. I began to suspect that all the hundred fortunes were calculated to please the customer. “Not at all,” the priest said. “You might have drawn 16.” He produced the corresponding paper and read: “Your career is not good. It is better to go home and start farming. There is a lot of gossip about you, and the emperor does not like you.”

I wonder if any prophet would have dared deliver a similarly grim forecast to the autocratic Emperor Wu.

Emperor Wu flung armies in all directions, expanding the empire into much of the territory that is today China, such as Yunnan Province in the southwest, and even occupying what is now northern Vietnam and Korea. But his fiercest campaigns took place in the northwest,

where the Han frontiers had long suffered raids by the Xiongnu, a nomadic people.

The patchwork of fortifications that one day would become known as the Great Wall was a sieve. Emperors had bribed Xiongnu chieftains, even presenting Han princesses as wives, but still the raiders came. Finally, in 133 B.C., Wu Di declared war on the Xiongnu. In a single campaign “the men and horses killed on the Han side amounted to over a hundred thousand,” Sima Qian wrote. But gradually Han rule was extended westward across what is today the Xinjiang Uygur Autonomous Region to the Pamir mountain range, 2,000 miles west of Changan. Expeditions even pushed beyond the mountains into Uzbekistan.

A lacework of tracks already crossed the vast Taklimakan Desert in Xinjiang. For years they had borne a trickle of goods; silk, iron implements, and lacquerware leaving China were swapped among desert dwellers for jade, furs, and horses. As Han armies pushed into the desert, the roads became more secure and the traffic exploded—the real beginning of the Silk Road land bridge between East and West.

Life survives in the Taklimakan only where springs bubble up or streams bring runoff from distant mountains. These oases became the outposts of empire, and I wanted to see them. So I hired an SUV with a driver, Wang Xihu, and asked Yang Yi Yong, *(Continued on page 20)*







PEOPLE IN LUOYANG "ARE EXTRAVAGANT IN CLOTHING,  
EXCESSIVE IN FOOD AND DRINK," WROTE A DISGUSTED  
OBSERVER OF HAN LIFE IN THE FIRST CENTURY A.D. EVEN  
SLAVES, COACHMEN, AND CONCUBINES WORE FINE  
BROCADES, PEARLS, AND JADE. ALL THE WHILE THE  
PEASANT'S LOT WAS WORSENING.



Death inspired such treasures as a suit of jade wafers (left). Belonging to Liu He, a member of the imperial family, the suit was believed to slow decomposition of a noble's corpse. Peasants, meanwhile, scratched out a living on the land with manual tools like this walking sickle (above) near the burial mound of Emperor Jing's favorite concubine, Li.

KUZHOU MUSEUM, KUZHOU





## PENS AND NEEDLES

Cui Zichong (above) practices the ancient art of calligraphy in a shop in the Beijing antiques district. Writing blossomed into an art in the later Han period, when the *Book of Odes*, a collection of earlier songs and poems, was etched onto lapis lazuli (above right). As a China scholar notes, writing became "a manifestation of one's moral character." From the healing arts has emerged a pointed debate: Are the meridian-like lines on a Han figurine reproduction (left) linked to modern acupuncture?

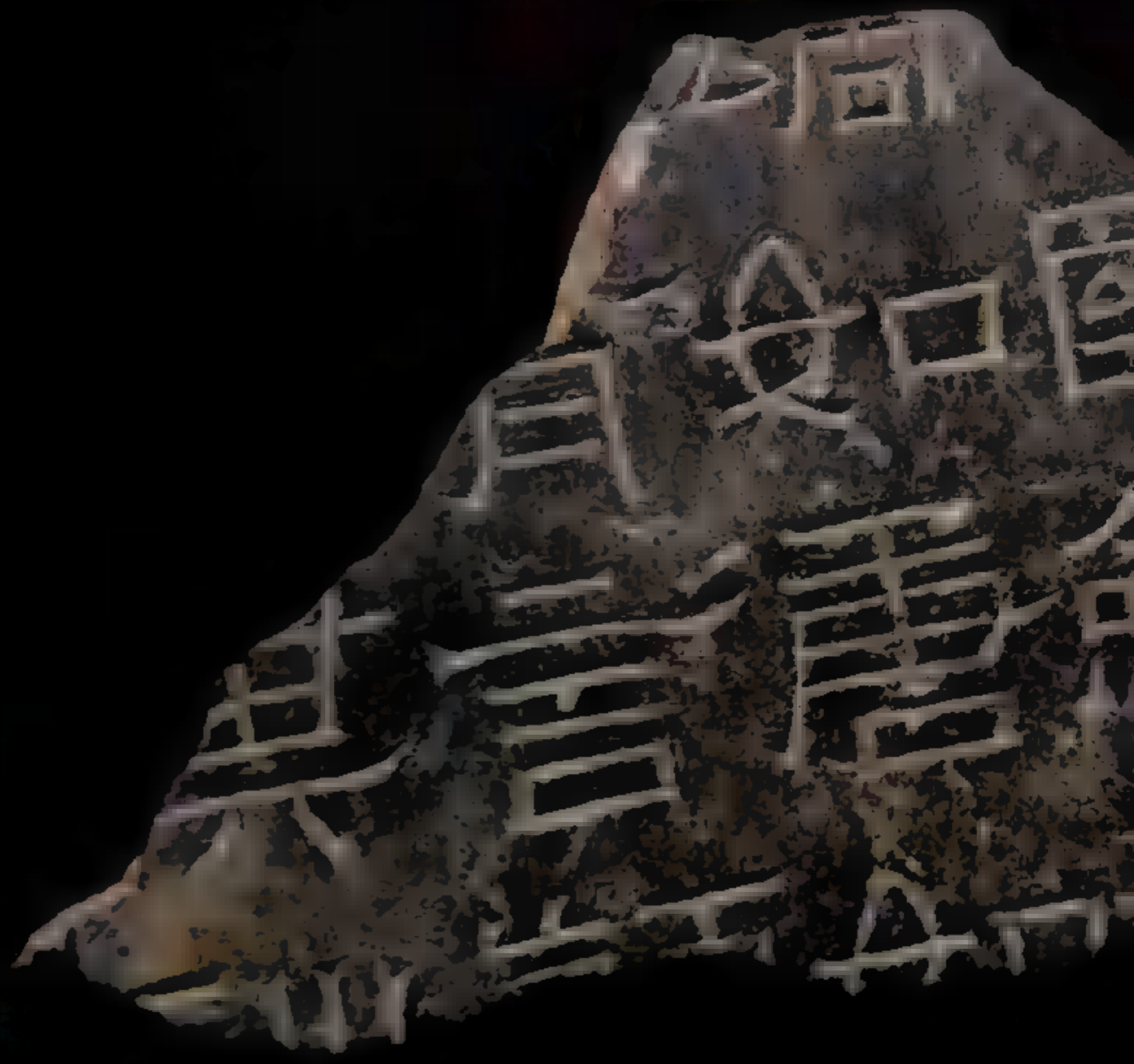
ROBERT CLARK (TOP LEFT); SIGUAN PROVINCIAL MUSEUM (BOTTOM LEFT); YANSHI SHANG CITY MUSEUM; YANSHI (TOP RIGHT)





今安在哉况吾與子漁於江之上  
一葉之扁舟舉匏樽以相屬窮  
於今之須臾長江之流不息而  
吾與子之相與也如波而逝矣

如北宮之困於子方其望也  
如北宮之困於子方其望也  
如北宮之困於子方其望也  
如北宮之困於子方其望也





an archaeologist who had worked years in the desert, to go along. Following routes on the desert's northern rim, we climbed parched mountain ranges and bumped across plains stretching into sun-blinded infinity.

I imagined strings of laden camels plodding our road. "Going both ways," Yang said, reminding me that in payment for silk China received nuts, sesame seeds, and grapes from Persia, spices and perfumes from India, and even glass from the Mediterranean. "Chinese traders sold their silk to Central Asian traders who sent it on toward Rome." By the beginning of the Christian era Romans were spending so much for silk that Emperor Tiberius prohibited the wearing of it.

To the oases, Yang continued, Han emperors sent not only soldiers but thousands of peasants—pioneers who would bulk up the empire's presence. The colonists encountered, besides Xiongnu, desert dwellers with Caucasian features, as proved by desiccated corpses exhumed from graves. One scholar told me: "I believe that when the Han came, the majority of desert people were white." Some experts say they may have migrated from Iran or even the Mediterranean. Or, others speculate, from southern Russia or Siberia.

One of the Han-occupied oases was in the Turpan Depression, 505 feet below sea level. At a humble open-air truck stop there, Wang drenched the SUV's radiator with a stream of water; the temperature was 110°F and a hard climb was ahead.

The road corkscrewed, surmounting ridges of naked rock. At last we topped out at 4,000 feet, and suddenly I was seeing grass and willows. Yang told me this was the oasis of Yanqi, the hub of a small kingdom in Han times and, because of its plentiful water, a crucial destination for caravans.

We climbed another barren mountain range and dropped down on Korla. Han caravanners knew this oasis too; rather, they knew the Korla that today is just rubble, with a few visible potsherds. Present-day Korla is a Taklimakan anomaly, a high-rise-studded mini-Houston for

oil fields far off in the dunes—a main source of China's petroleum. Billboards urge petroleum executives to wear three-piece suits with such brand names as Tiger and Achievement. (No three-piece Tigers or Achievements on the streets in hot May, however.)

Next morning we headed west from Korla on a lonely highway that coursed through thornbush and stunted tamarisks. Occasionally we came on the stubby remains of Han fortifications, made of pounded earth, and even an intact lookout tower rising 45 feet. Guard duty



A second-century B.C. gold belt buckle belonging to a Han king, Liu Wu, graphically depicts a bear and tiger overpowering a horse.

in these places must have seemed like exile to the most desolate corner of the world.

The small city of Kuqa was a welcome smear of green on the horizon. A Han headquarters, it still possesses part of its ancient wall. Modern Kuqa, hard by the ruins, moves substantially on horsepower and donkey power, although some wealthier folk travel by motorbike. Almost everyone is Uygur, a Turkic people. Numbering more than seven million, Uygurs are Xinjiang's largest population group. Though they are Muslims, with strong cultural ties to Central Asia, their original homeland was the Mongolian steppe, from which they fled in the ninth century A.D. One of the surprises of the Taklimakan is that its hostile wastes have sheltered a succession of peoples on the move.

Kuqa's Friday bazaar beckoned crowds to buy from heaps of practical goods such as buckets, rope, and bicycle parts. In a smoky pavilion kebab sellers vied for business. "Come here!" they called. "Here's a table!" Women flashed through the crowd in red and lavender dresses and spangled scarves. Beyond the kebab cooks awaited the



rice sellers and their mounds of grain and then the shoe repairmen, who fastened soles with a few turns of hand-cranked machines.

It is, altogether, a classic Central Asian bazaar, like those I've seen in Afghanistan, and to my mind it is a national treasure. I'm not sure China agrees. The present regime has compelled hundreds of thousands of Han to move into Xinjiang to dilute the dominance of the sometimes restive Uygurs. Emperor Wu had a similar purpose in mind, of course, when he dispatched Han peasants to the oases.

**W**u Di's marathon reign ended with his death in 87 B.C. His military campaigns had taken the dynasty to its peak of dominion and prestige. But the cycle of yang was sliding into yin. War expenses had drained the treasury. Profiteers "were busy accumulating wealth and forcing the poor into their hire," Sima Qian chronicled. Other peasants were being squeezed onto smaller plots of land while the estates of well-connected landlords grew larger. The widening gap between rich and poor would become the dynasty's most explosive problem.

At court, powerful families were jockeying to control the throne and share its riches. When Wu Di's first empress faced demotion—she had failed to bear him an heir—a daughter intervened, attempting to rescue the situation by witchcraft, a serious crime. Her scheming led to the slaughter of hundreds of implicated people.

Nor should we overlook the manipulations of a beautiful commoner named Flying Swallow, who flew high indeed, becoming empress in 16 B.C. A favorite of Emperor Cheng, she managed to depose his chosen empress by accusing her of the same evil, witchcraft. Jealousies and scheming spawned years of feuds, executions, and even pitched battles, weakening the Liu clan's grip.

And finally, a coup. In A.D. 9 Wang Mang, member of a powerful family, was emboldened to shove aside the wobbling Liu regime and usurp the throne. After 215 years, Han rule was ended, he proclaimed, and a new dynasty was beginning, called just that: Xin, "new."

Scholars debate whether Wang Mang represented yin or yang. To redress the distorted land ownership pattern, he set out to dissolve the bloated estates of the Lius and dispense their holdings to the peasantry. But after 14 years he

had not succeeded, and the peasantry did him in, in consort with the Yellow River.

China's mother river, as it's called, the Yellow River was the lifeline of many dynasties, providing a 3,000-mile-long route for trade, transportation, and irrigation. But she was a violent matriarch. In Wang Mang's reign the river went on a terrible rampage. Fleeing peasants became mobs of hungry looters, triggering a full-scale rebellion. Red paint smeared on their foreheads, an identity badge, inspired the name by which the rebels were known, Red Eyebrows. Wang Mang tried to restore order, but the Red Eyebrows were invincible. In A.D. 23 they entered Changan and lopped off Wang Mang's head.

Once more the throne was up for grabs, and in the chaos the Liu clan saw its opportunity. Liu Xiu, a ninth-generation descendant of the dynasty's founder, proclaimed himself emperor. While the Red Eyebrows sacked Changan, he led his followers to Luoyang and inaugurated Han Chapter II. The rebellion died out and the Lius were back in business for another 195 years. Historians often refer to the Han reign in Changan as Former Han or Western Han, while the Luoyang era is Later Han or Eastern Han.

At noontime in Luoyang I watched a boy kick his soccer ball down a street almost empty of traffic. Compared with throbbing, neon-lit Xian, Luoyang is gray and muted. An unfinished high-rise hotel stands forlornly near the city center.

The site of the Eastern Han capital, a few miles away, reminded me of Changan, with remains of the city wall rimming grain fields and cabbage plots. A low mound is all that's left of the observatory where astronomers tracked the heavens. "They made the dynasty's calendar and told the time for planting," said archaeologist Duan Pengqi, who spent years excavating at Luoyang. "If anything unusual happened, such as a planet turning bright, they reported it to the emperor because it might be a sign of something momentous about to occur."

The Liu scion who reestablished Han rule, known today as Guangwu Di, was a strongman who reigned at Luoyang for 32 years, until A.D. 57. His capital was one of the world's most populous cities, with perhaps half a million inhabitants and palaces that rose several stories.

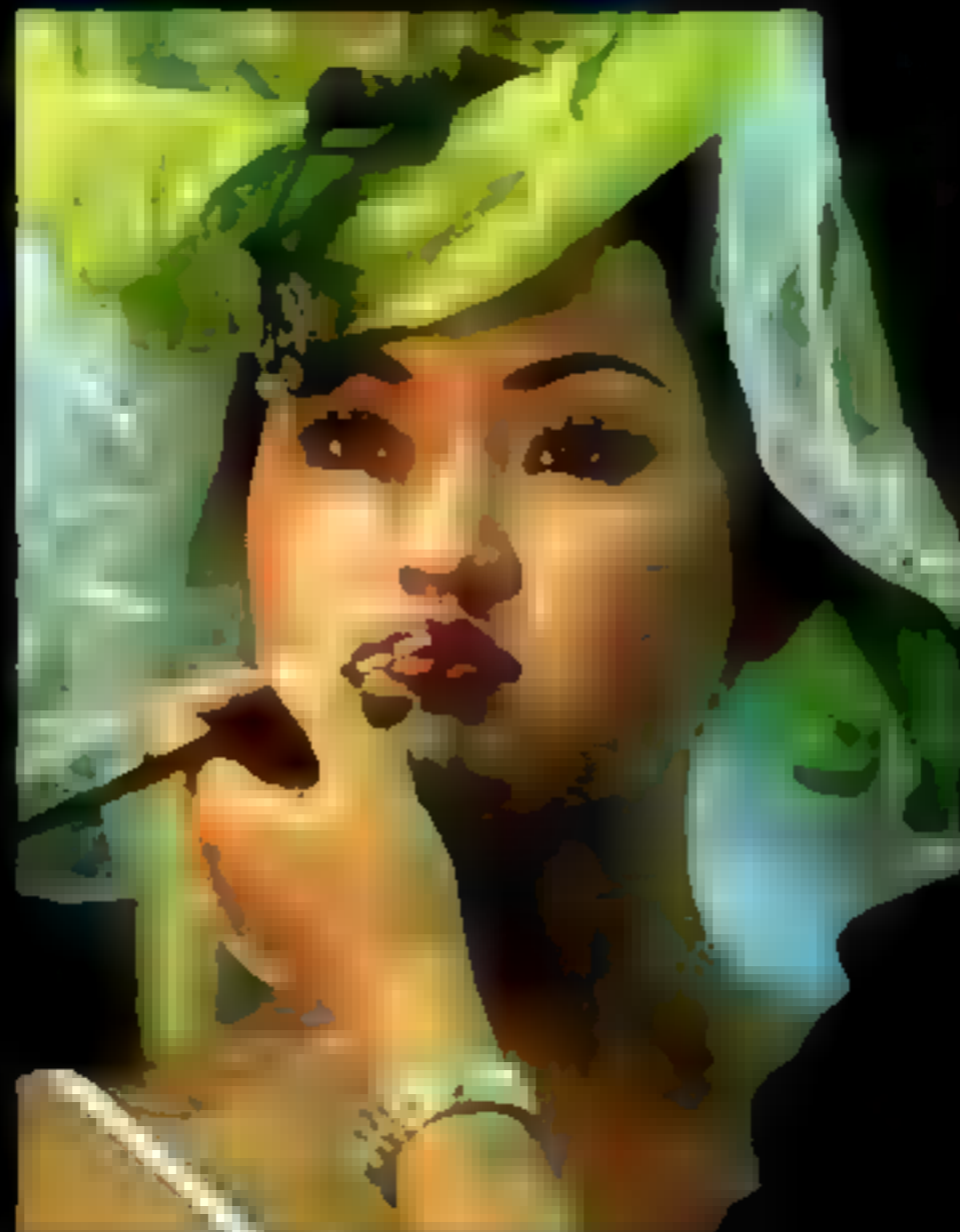
Life in those palaces was indubitably grand. I looked in one day on a party, recorded on the brick wall of a tunnel (Continued on page 26)







AFTER LIU BANG'S DEATH IN 195 B.C., HIS EMPRESS, LU ZHI, TRIED TO HIJACK THE EMPIRE FOR HER OWN FAMILY. SHE HAD SEVERAL OF HIS SONS MURDERED AND MUTILATED HIS FAVORITE CONCUBINE, THEN HAD HER TOSSED INTO A PRIVY. THIS WOULDN'T BE THE LAST TIME AN EMPRESS OR CONCUBINE COLLUDED IN A DANGEROUS POLITICAL GAME.



A terra-cotta figurine of a servant girl (left) found in the grave of a nobleman wears a splash of color on her lips. Cosmetic boxes were often placed in women's tombs, signifying the timeless allure of the painted face. More recently makeup adds highlights to the already elegant features of model Han Ping (above), preparing for her job of attracting business to a Beijing photo studio.

YANGLING MUSEUM / YANGLING (LEFT) / ROBERT CLARK (ABOVE)





## BODIES IN MOTION

Antics of the Shaanxi Acrobatics Arts Association delight crowds (above) in Xingqing Park in Xian. Displaying the Han love of entertainment two millennia ago, an acrobat teeters on the lip of a cup (above right). A mural (left) discovered in the tomb of a wealthy member of the Han elite conveys wishes for a festive afterlife with its scene of a dancer twirling in front of banquet guests. Hopes for happiness in the present spring from the fluid movements of two Uygur women (right) dancing at a wedding in the western region of Xinjiang.

(ROBERT CLARK (LEFT AND RIGHT); LUÓYANG MUSEUM, LUÓYANG (TOP RIGHT))











36 steps below ground. The honoree wore a festive red dress. She was seated at one end of a great hall with many guests who were being entertained by jugglers and musicians.

Artists painted this scene, which is about 25 feet long, in a tomb at Xinmi in Henan Province, where the honoree and her husband were buried. "We can't be sure who she is," said the tomb's curator, Wang Mingliang, "but we believe the scene represents some important occasion in her life." The tomb's construction and decoration probably required the labor of a hundred artisans for six or seven years. Many royals were interred far more elaborately, their bodies encased in, and

supposedly preserved by, suits of jade wafers stitched together with gold wire.

People in Luoyang "are extravagant in clothing, excessive in food and drink," wrote a disgusted observer of Han life in the first century A.D. Even slaves, coachmen, and concubines wore fine brocades, pearls, and jade.

All the while, the peasant's lot was worsening. For the desperate poor, selling one's self into slavery was an option, although the number of slaves apparently never became large. More likely, an indebted peasant forfeited his small plot to a landlord and became indentured. As estates grew bigger, so did the numbers of unemployed





who roamed the countryside looking for work.

Perhaps one of those had been Cao Fu, whose name appears on a crude gravestone collected from a Luoyang cemetery for convicts. Cao died while serving the five-year sentence of another man, Hu Fei. "A rich man convicted of a crime could hire a substitute prisoner," archaeologist Duan explained. "We think very few public officials were imprisoned."

Impoverished peasants, and also some aristocrats, must have sought escape from the gathering storm at a Buddhist temple a couple of miles from old Luoyang. On shady paths there I followed pilgrims moving reverently from altar to

**SACRED SILHOUETTE**, Mount Tai (foreground) has over time beckoned philosopher, emperor, and tourist to Shandong Province. Its name meaning "exalted," the peak may have humbled Confucius, who is said to have pronounced from its 5,000-foot summit, "I feel the world is much smaller." In his quest for immortality, Wu Di became the first Han emperor to ascend the peak, where he sought to commune with the gods. Poems today decorate stones on the trail to the top, a path followed by modern visitor Hu Hui, who says, "I think Mount Tai is famous not for its natural scenery but for its cultural scenery."



altar. Many were poor folk who bore simple offerings—two or three peaches or apples. A gong's throaty resonance lingered among the junipers.

A monk named Zhang, who walked with me, said two monks brought the faith to Luoyang around A.D. 67, having entered China via the Silk Road. "They brought statues and scriptures on a white horse," Zhang said. Thus the temple's name today: White Horse. From this and other founts Buddhism expanded across China, joining Confucianism and Daoism—the three teachings, as Chinese call them—as a profound influence upon future dynasties and China's masses.

**T**oward the end of the first century A.D. the house of Liu stumbled into a long streak of bad luck in which one emperor after another died young, without a chosen heir, or without sons at all. The new emperor might be a child (perhaps a cousin of the deceased ruler) or even an infant. Real power usually resided in a regent from the family of an empress (even child rulers were provided with empresses). Court scheming intensified.

Yin, yang. While the aristocrats jockeyed, a remarkable device was installed in the Bureau of Astronomy and Calendar. Six feet wide, it looked like a bronze jar. Eight dragon heads were placed around its upper part. Beneath each was a bronze toad. If the jar felt an earthquake's tremor, even a faint one, a ball dropped from a dragon into a toad's mouth. The genius of this, the ancestor of all seismographs, was that the ball dropped in the direction from which the tremor came, thanks to a mechanism inside the jar. Some engineers believe it was a pendulum suspended from a sling with eight levers attached to the eight dragon mouths. If a tremor came, say, from the south, it caused the lower part of the pendulum to swing north. Therefore, the upper part tipped south, engaging the lever attached to the southern dragon. Its mouth opened, the ball dropped. Thus Zhang Heng, who invented his "earthquake weathercock" in A.D. 132, could inform the court if a distant earthquake occurred, and indicate the direction of the stricken area.

Zhang's device surely registered several tremors that, along with other calamities, such as floods and locust swarms, led prognosticators to conclude that heaven was angry and the end of the dynasty was approaching.

**TWO GIANTS** who changed the course of China, Confucius and Mao Zedong, share space at a street stall in Qufu, near Mount Tai. While Mao preached revolution, the Han rulers sought order and stability, promoting Confucian principles that still resonate in today's China.

Indeed, everything was spinning out of control. Thousands from Luoyang's Confucian academy protested corruption—China's first student demonstrations. At court, eunuchs, once merely servants and harem guards, became a potent force in the often bloody scheming, enriching themselves as they supplanted purged officials. Massive peasant uprisings roiled the provinces "like a billowing sea," as one historian wrote, even threatening the capital in A.D. 184.

Six years later a general named Dong Zhuo seized power and placed a child, Liu Xie, on the throne. Last of the 27 Lius to be called emperor, the puppet was powerless to rescue the empire of his forefathers. Dong murdered the eunuchs and burned Luoyang to the ground. Warlords battled each other. Liu Xie finally abdicated in 220, and China broke into warring states, not to be unified again for three and a half centuries.

Seen close-up the Han nobility looks less than noble. But at that range other dynasties look no better. The Han's supreme goal was maintaining itself, and despite bouts of turmoil, it succeeded so well that centuries later, when China was scourged by civil war and nomad raiders were plundering northern towns, people looked back longingly to Han unity and peace.

And it really never died, this dynasty, transmitting cultural precepts and beliefs still valid. "The West inherits its traditions from the Romans and Greeks," summarizes Liu Qingzhu, director of the Institute of Archaeology in Beijing, "while China inherits from the Han." Later dynasties would be more renowned, praised for artistic perfection and sophisticated governance. But the Han gave them a foundation—an impressive achievement for a regime sired by a coarse upstart who liked to befoul scholars' hats. □

**WEBSITE EXCLUSIVE** Winds as strong as tornadoes, the hazards of rice wine, the challenges of photographing a farmer's market—get the author's and photographer's tales from the field at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).







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P O L A R   B E A R S

W H I T E

**Nosing into frigid wind, a polar bear sniffs for prey. About 1,200 of these majestic carnivores haunt the western edge of Canada's Hudson Bay. Here near the southernmost tip of their range, they're treading on thin ice.**





ON WHITE









BY JOHN L. ELIOT NATIONAL GEOGRAPHIC SENIOR WRITER

PHOTOGRAPHS BY NORBERT ROSING



Two burly males shove and snarl for more than half an hour under an October sun. This is more dance than duel. Invigorated as summer heat yields to autumn chill, polar bears playfully wrestle, which may help them hone fighting skills, tone muscles, and assess the strength of rivals. In the fall, males aren't competing for food or mates. But as winter ice forms on the bay, the bears move out alone to hunt for seals and, in spring, for partners.



Rocking  
tundra  
males slam  
together in  
mock combat  
could hear their  
paws whistling  
through the air,  
says photogra-  
pher Norbert  
Rosing. These  
bears each  
stand nearly  
nine feet  
tall and may  
weigh one thousand  
pounds.











**WAITING GAME** An eager swimmer braves choppy ice forming near shore in late October (above). Until the bay freezes, polar bears (*Ursus maritimus*) lounge, fast, and frolic near the town of Churchill. Norbert Rosing spied one getting showered by snow when it shook a willow branch (top right). Another seemed to bathe in a drift (center). At one point a wolf trotted past a pair of unconcerned bears (bottom). The animals may have been attracted by a nearby carcass.

Like all polar bears, those on Hudson Bay need solid ice as a platform for hunting seals and seal pups, their main prey. Yet the bay is frozen only in winter and spring, so from July to November bears must live off their fat reserves. For millennia they've coped, but climate change may be tipping the balance. "Though there's considerable variation, spring breakup is two weeks or so earlier now than it was 20 years ago," says biologist Ian Stirling of the

Canadian Wildlife Service. His data show that birthrate and adult bear weight are both down about 10 percent from 1980. "If the trend continues and the ice disappears from Hudson Bay," says University of Alberta biologist Andrew Derocher, "it's pretty clear that these bears will disappear too."



**WEBSITE EXCLUSIVE** See polar bears in action: Norbert Rosing narrates a multimedia special about these predators at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).











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## DOWNTIME



**Like a dormant volcano hot at its core, a big male snoozes in snow. Even at subzero temperatures, polar bears retain virtually all their body heat. Two layers of fur and thick fat act as superb insulation.**









Four-footed surrender (above) and head chomps with feigned ferocity (opposite) form part of the play-fighting repertoire. Worn out from their rumpussing, these two males eventually took a break, with one using the other's head as a pillow (left). In these fall matches, "their testosterone is low, so there's no real aggression," says biologist Andrew Derocher. "It's like each is trying to find out whether he's a Volkswagen or a Jaguar."









**A roaring male lunges and lifts his paw to bash another male that comes too close. (The newcomer dodged the blow.) It's unknown whether polar bears have true social hierarchies, but individuals can prove physical dominance with sheer force.**









**Muzzle frosted in snow, a cub peeks around a drift (above) as its twin and mother relax. The cubs are about three months old and perhaps a week out of their den in Wapusk National Park. Now, in March, mom is leading her playful clan—with stops for nursing and rest—to the frozen bay where she'll hunt for seal pups born on the ice and eat for the first time in months. As the ice melts, bears lumber inland to wait out summer. Pregnant females dig their dens in fall, starting the cycle again.**

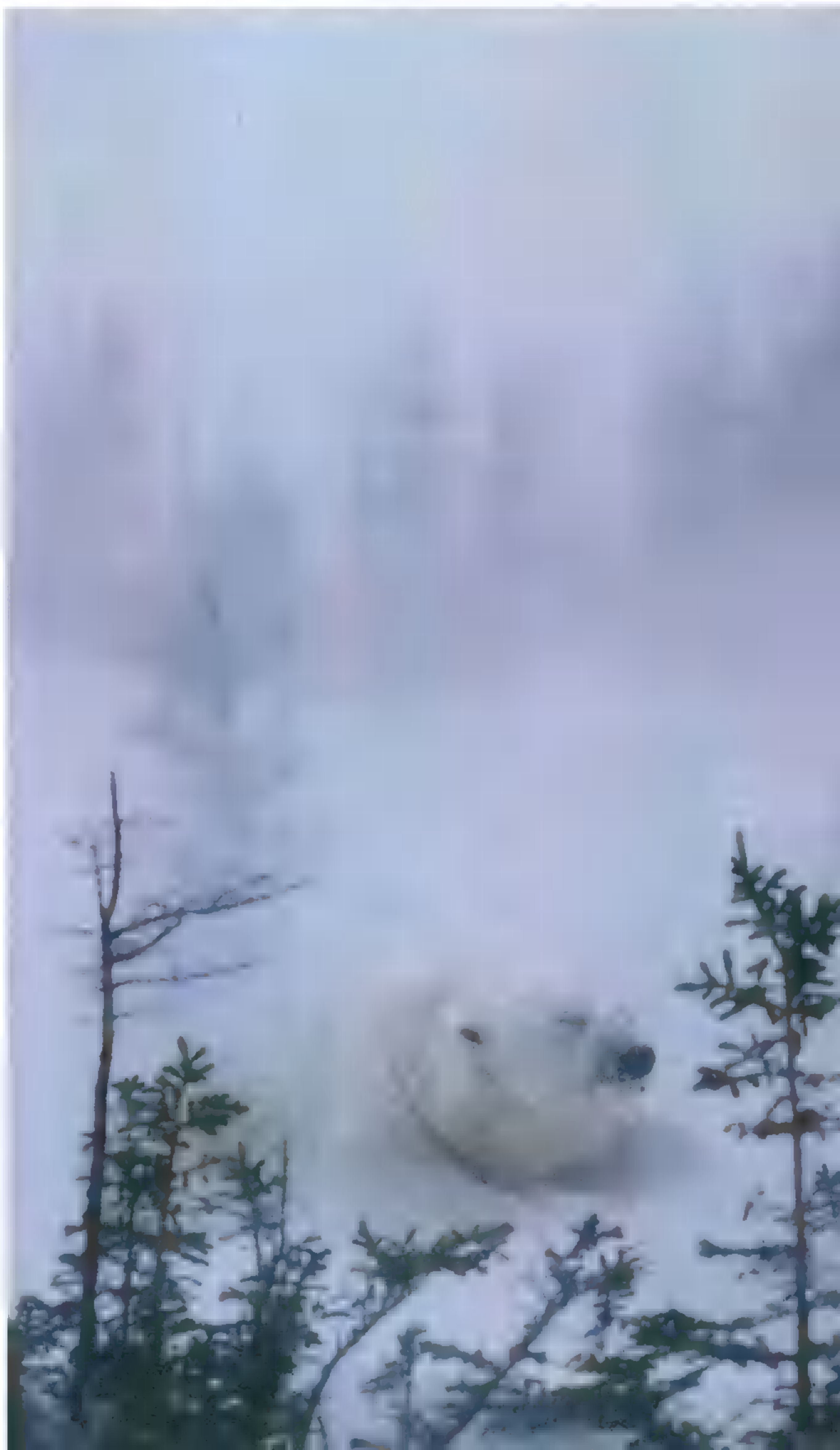




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## WAITING FOR WINTER

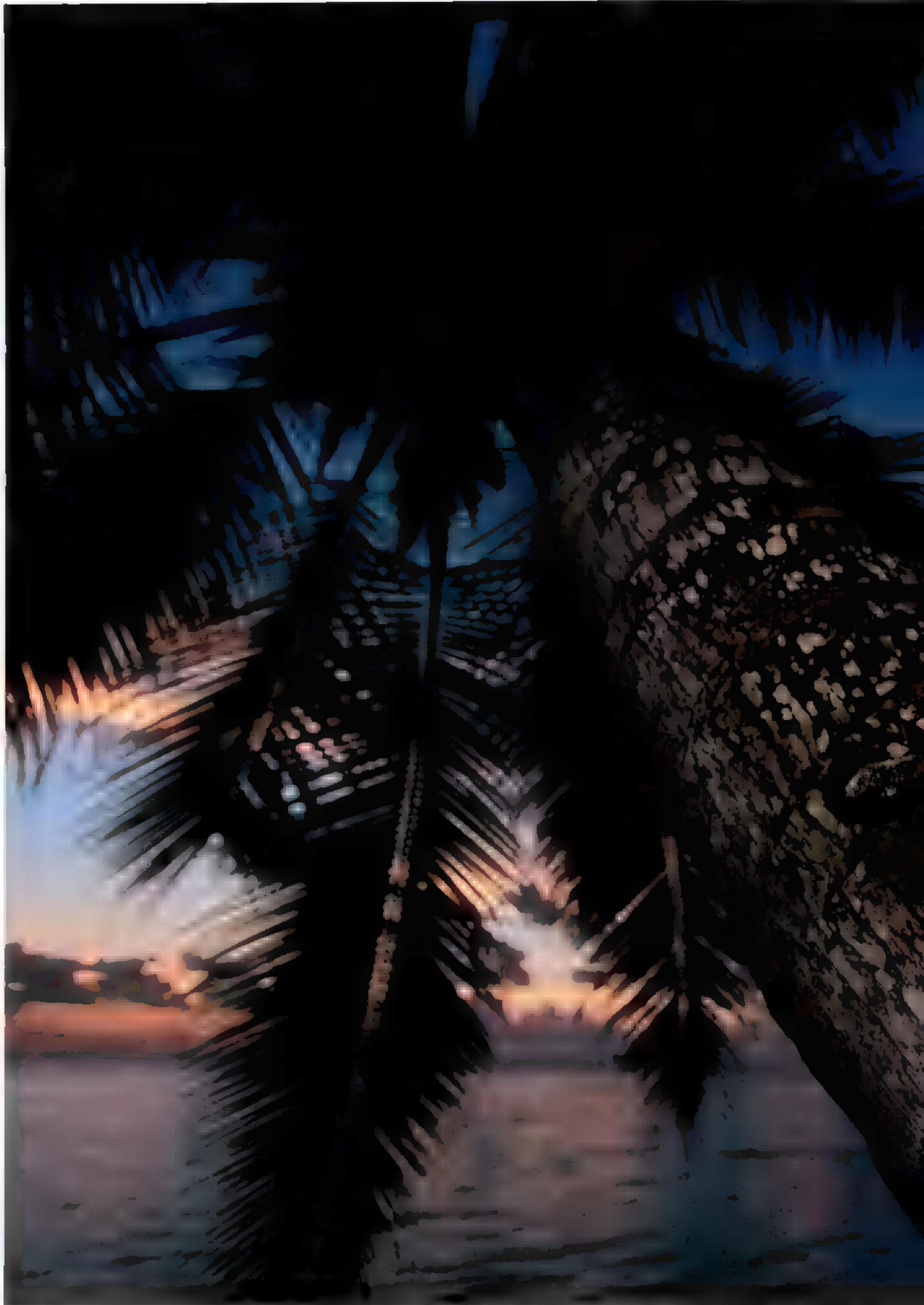
A dozing bear won't lie for long as autumn blizzards hit. Snow, cold, and the promise of food will lure him toward Hudson Bay to stalk the winter ice. With ice tending to melt earlier in the spring, the winter hunt grows urgent. □











A CORAL REEF WILDERNESS REVEALED

# PHOENIX





OVERHARVESTED ELSEWHERE IN THE PACIFIC, COCONUT CRABS AS FAT AS FOOTBALLS THRIVE ON THIS UNSPOILED ARCHIPELAGO.

# ISLANDS

By GREGORY S. STONE

Photographs by PAUL NICKLEN

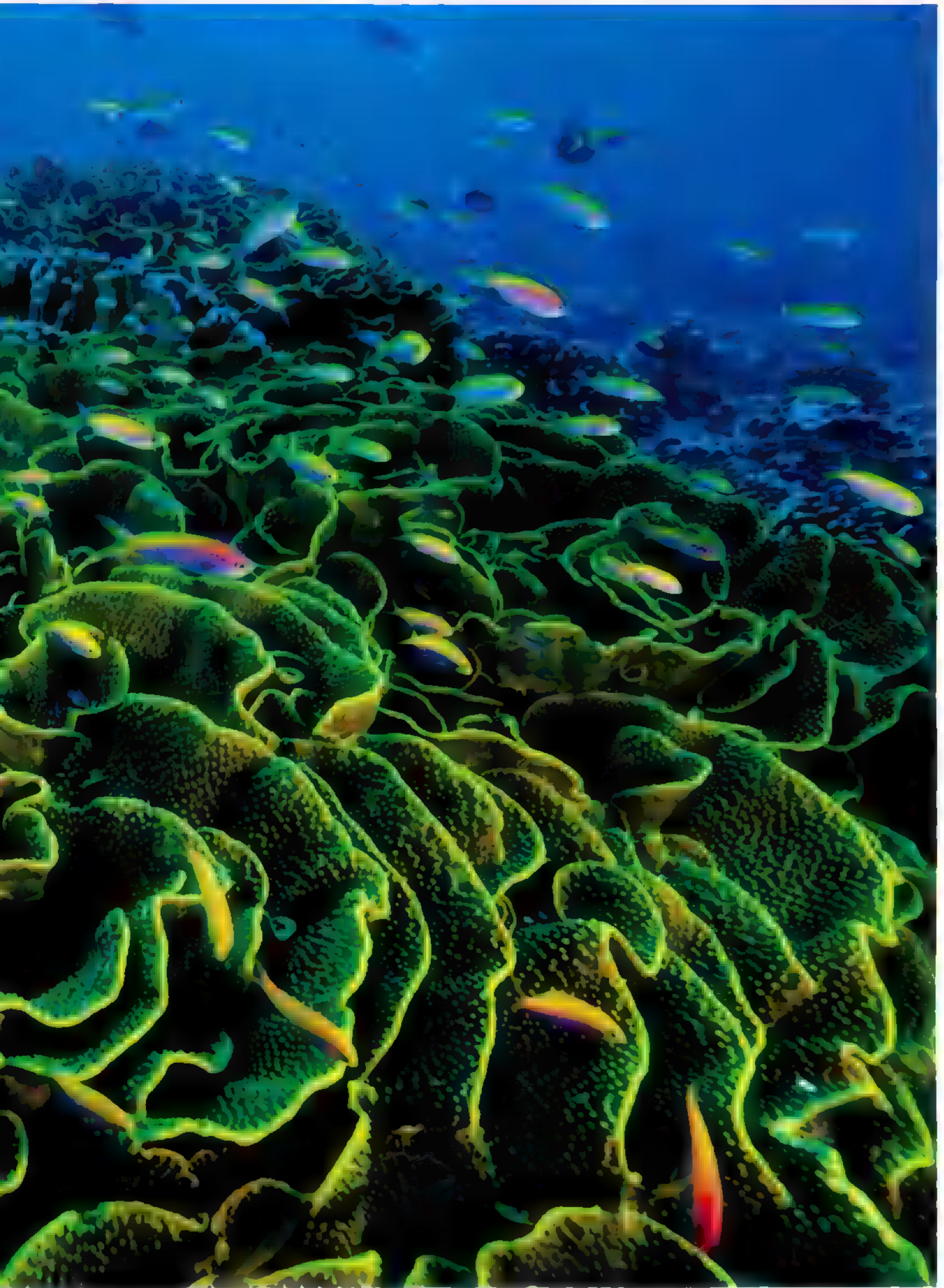




FAIRY BASSLET FISH DART AMONG BLOSSOMS OF LETTUCE CORAL. HEALTHY REEFS ARE ESSENTIAL TO THE SURVIVAL OF THE

SUN STREAMED DOWN, BRIGHTENING





FRAGILE ATOLLS WITHOUT LIVING REEFS, WARNS BIOLOGIST DAVID OBURA, "THESE ISLANDS WOULD QUICKLY ERODE AND DISAPPEAR."

YELLOW, GREEN, AND PURPLE CORALS.





PROTECTED BY A SEA ANEMONE'S TENTACLES, AN ORANGE-FIN ANEMONEFISH INSPECTS THE BRIGHT CLUSTER OF EGGS HIS MATE HAS JUST LAID.

OUR MOST VALUABLE DISCOVERY WAS THAT





THE ANEMONE RECOGNIZES THE FISH AS FRIENDLY AND WON'T STING IT. ■ RETURN, THE FISH GROOMS THE ANEMONE AND CHASES OFF PREDATORS.

AN ENTIRE CORAL ECOSYSTEM HAS SURVIVED.



A RAUCOUS CLOUD OF TERNS hovered over Kanton island, calling out in high-pitched screeches. Beyond the low sandy atoll, the South Pacific stretched forever beneath tropical clouds topped by immense crowns of gold, red, and white. It was 6:30 a.m., and biologists David Obura, Sangeeta Mangubhai, Mary Jane Adams, dive master Cat Holloway, and I adjusted our scuba gear as we sat on the pontoon of the gently rocking skiff.

"This is definitely the spot," David said. "Let's hope they're here."

I bit onto my regulator, grabbed my underwater camera, and fell backward into the island's narrow lagoon entrance. The others followed, and we descended 70 feet to the bottom. Streaming through the water, the morning sun brightened the yellow, green, and purple corals around us. A manta ray and a green turtle nosed nearby as if curious.

Then, like the start of a breeze, the water began to move. Nearly imperceptible at first, the strengthening current gradually diverted our bubbles at a slight angle as they ascended. The flow increased steadily and a roar replaced the peaceful silence as water began to gush out the lagoon's entrance into the ocean on the full moon ebb tide.

Cued by this outgoing current, a school of perhaps 5,000 Pacific longnose parrotfish gathered around us and started to circle. Our bubbles were flowing sideways now as we clung to bottom rocks, and our hair and dive gear flapped and fluttered in the torrential tide. If we had let go of the rocks, we would have been swept out into the ocean.

The foot-long parrotfish tightened their school and swam faster. This was what we had come here to see: the periodic spawning of the parrotfish on the outgoing tide. Within the group, a few fish swam faster and shook, stimulating the entire school to spiral and bolt upward, releasing ecstatic bursts of eggs and sperm along the way like biological fireworks. The egg and sperm clouds they left behind were so dense they dulled the penetration of sunlight through the water.

Again and again the fish repeated this act, spiraling toward the surface every ten to fifteen seconds. For almost an hour the school exploded in a rite of reproduction, relying on

the fast ebb tide to carry the fertilized eggs far out to sea, where they would be safer from predators. As I watched from the seafloor, a large shadow passed over me. A half-ton manta ray, hovering magically and somehow unmoved by the current, was feeding serenely on the parrotfish eggs and sperm.

TOO SOON, our nearly empty air tanks forced us to return to the surface and our waiting skiff.

"Incredible—I've never seen anything like it!" said David, a specialist in coral reefs who has spent more than a thousand hours underwater studying ocean life. I also was deeply moved. As vice president for global marine programs at the New England Aquarium, I've made it my goal to find Earth's last pockets of primal ocean, those underwater havens that have remained unspoiled as long as the ocean can remember. Here in this lagoon we had discovered such a place.

We'd motor-sailed five days out from the Fiji Islands to reach the Phoenix archipelago: eight small islands, including Kanton, strung like jewels on an irregular necklace. The islands cover 25,000 square miles of the Pacific, about one-fifth the area of Australia's Great Barrier Reef, and are part of the Micronesian country of Kiribati (pronounced *KEE-ree-bas*).

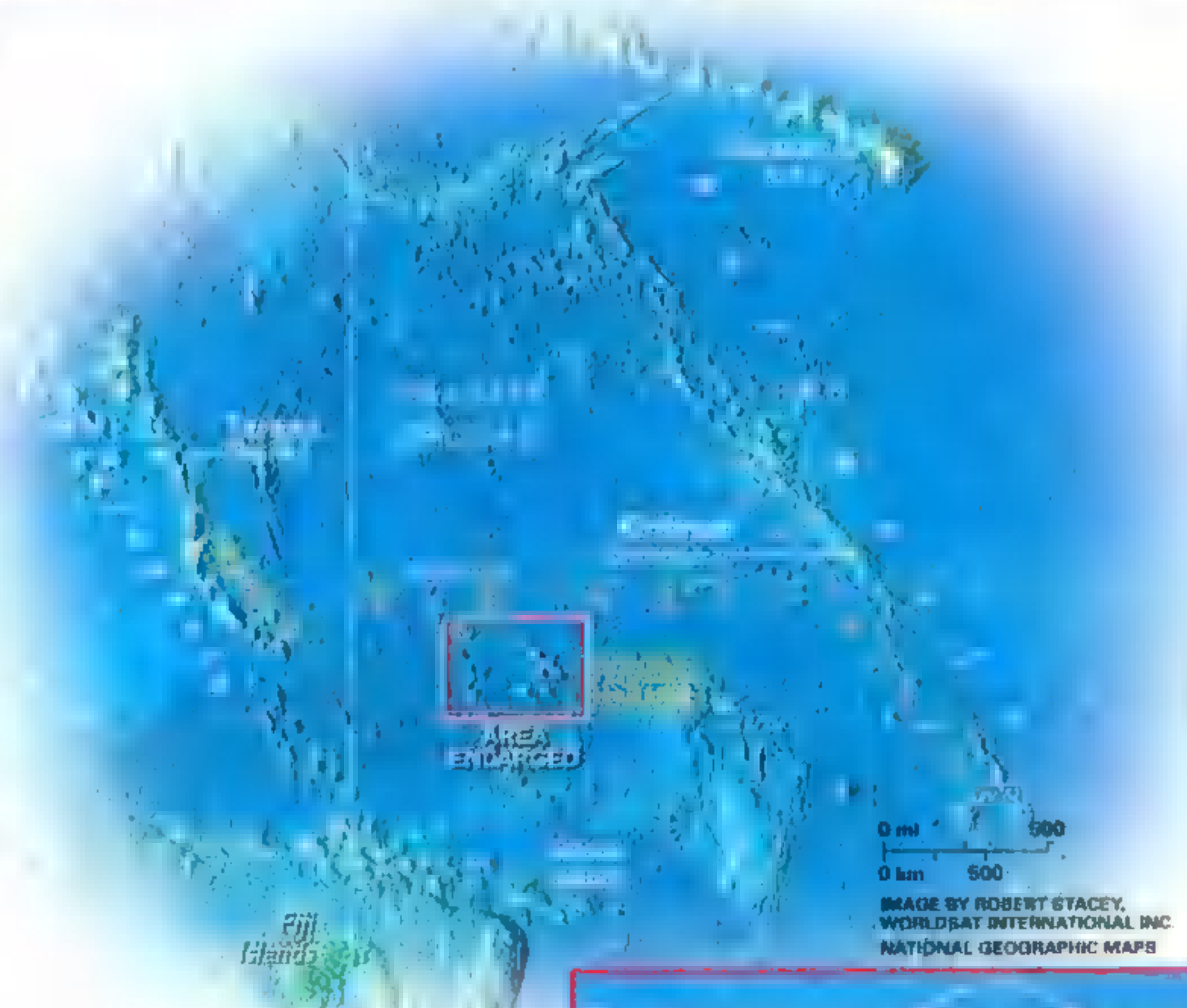
Most of the 93,000 people of Kiribati don't live on the Phoenix Islands. All but a few live 600 miles to the west on the Gilbert Islands or 1,000 miles to the east on the Line Islands. Kanton is the only permanently inhabited island in the Phoenix archipelago. But what they lack in human population, the islands make up for in animal life, much of it revolving around magnificent coral reefs that keep marine biologists like me awake at night thinking of undiscovered species they shelter.



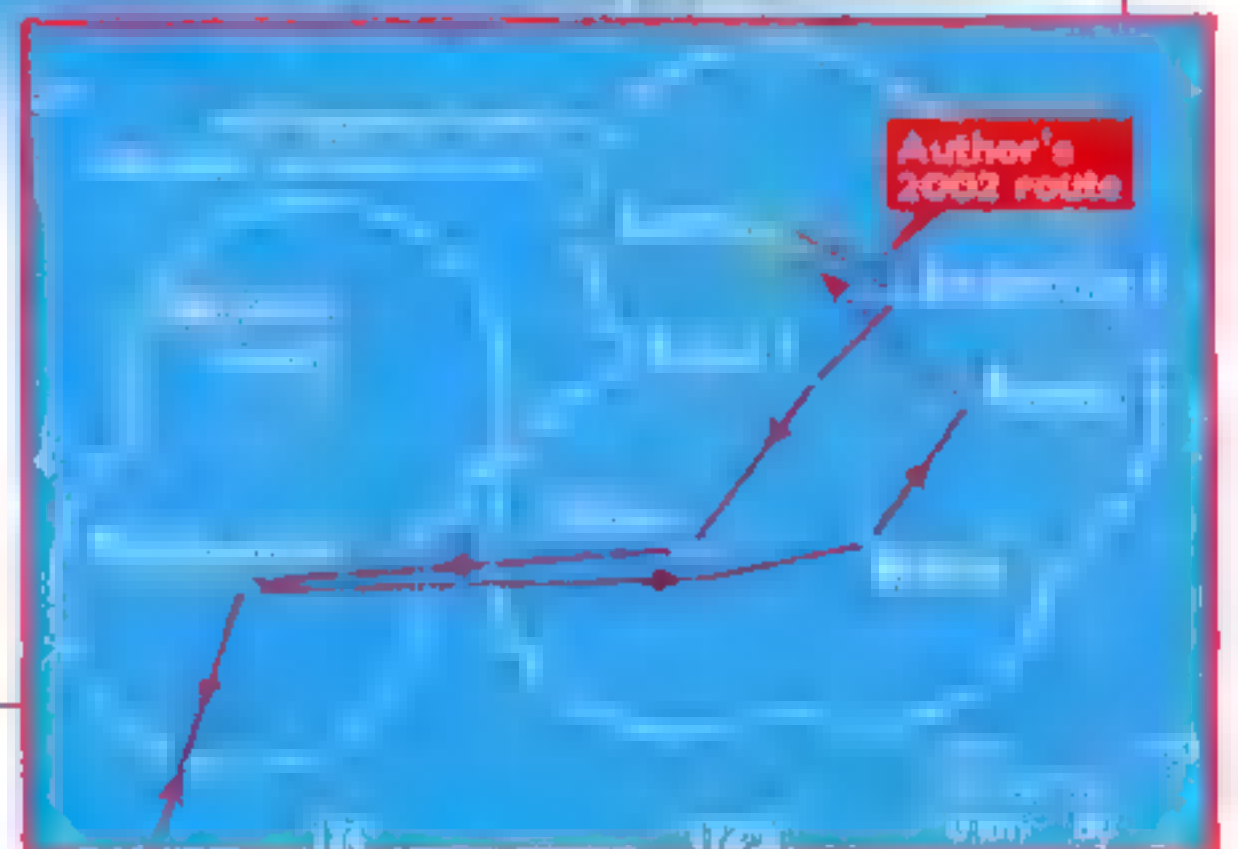


## PRESERVING PRIMAL OCEAN

A skiff slicing across Kanton's lagoon (above) carries scientists on a biological survey of the Phoenix Islands. The archipelago's isolation and lack of fresh water have kept it mostly uninhabited and helped preserve some of the world's last pristine coral ecosystems. Part of the nation of Kiribati, the eight atolls lie scattered over an area about the size of West Virginia. With scant land resources and only 93,000 citizens, the country relies on revenue from commercial fishing licenses. Still, to protect the Phoenix Islands' marine environment, officials are banning foreign purse-seine tuna boats within a 60-nautical-mile exclusion zone. Kiribati leaders are also working with the New England Aquarium on a



proposal to the Global Conservation Fund to restrict reef fishing and to create an endowment that would reimburse lost fishing revenue.







## SHARK POPULATIONS DON'T BOUNCE BACK QUICKLY. LOCAL SPECIES GIVE BIRTH TO ONLY A FEW LIVE YOUNG EACH YEAR.

I had first visited the Phoenix Islands two years before on a scouting trip arranged by Cat Holloway and Rob Barrel of Naia Cruises in Fiji. Encouraged by what I had seen, I chartered their 120-foot sloop-rigged motor sailer *Naia* to return in June 2002 with an 11-person scientific expedition to survey the biodiversity of the world's last unexplored oceanic coral archipelago. Underwater we would assess the health of various species of hard coral upon which, and within which, live fish and invertebrates such as sea cucumbers, giant clams, nudibranchs, and sea stars. On land we would study the islands' tropical vegetation and abundant birds.

Our first destination was Nikumaroro, a densely vegetated island with a shallow lagoon known for its abundance of sharks. Our plan was to count sharks in the upper reef and to seek new species of other fish in the deep reef zone. Rob found an anchorage for *Naia* off the island's western point.

Carrying my scuba gear and cameras, I made my way down *Naia's* side deck to the

dive skiffs tied off her stern. Jerry Allen, an ichthyologist with Conservation International, and Steve Bailey, another scientist from the New England Aquarium, joined my wife, Austen Yoshinaga, who is also a researcher at the aquarium, and me in the skiff. Our excitement was tinged with concern as we sped toward the island and *Naia* disappeared from view around the point. The shadowy outlines of sharks darted beneath us in the clear water. When we got within 200 yards of Nikumaroro's south side we slowed the skiff to an idle. We could see the narrow lagoon entrance and palm trees jutting up through the island's dense undergrowth.

"OK, let's go," I shouted as we rolled backward into the water as a group for safety.

Divers are most vulnerable to sharks at the surface and in mid-water, so I wanted to get to the seafloor quickly. Austen and I tucked in among the coral heads at 60 feet, then watched Jerry and Steve continue over the edge of the reef into deeper water, where they would search for well-hidden reef fish.





*Baby blacktip reef sharks circle the toes of a dive guide in Nikumaroro's lagoon (left), their home until adulthood, when they'll move to outer reefs. Near Kanton, a gray reef shark (above) lies snared in a local fisherman's net. Such subsistence fishing poses little threat to shark populations, unlike foreign commercial fishing vessels, one of which took thousands of sharks in 2001.*

The water around Austen and me was filled with gray, whitetip, and blacktip reef sharks. They appeared to be hunting for food amid a school of some 2,000 striped convict surgeonfish that were grazing on algae along the bottom and several hundred bigeye trevally that passed above us. Sharks generally don't attack divers without provocation, but their shape and manner can nonetheless have an unnerving effect on you.

We moved down the reef. Austen was carrying a blunt, two-foot plastic "shark stick" to hold off curious or aggressive animals. "False security is better than no security," she had told me back on the boat. I planned to use my underwater video housing, the size of a car battery, if I needed a shark deterrent.

Turning back toward Austen, I saw silhouettes of sharks behind, above, in fact all around her. As I looked ahead, a six-foot gray reef shark shot at me like a torpedo. I hadn't been paying enough attention and didn't spot it earlier—and apparently it was surprised by me too. I stiffened, kicked back, and thrust

my camera housing toward it. It veered and darted away like the snap of a whip, passing in a blur only eight inches away from me.

We completed our shark count without further incident. "I've never seen so many sharks!" Austen said as she pulled herself back into the skiff, clearly glad to be out of the water. We were gratified to find the shark population so healthy, having counted over a hundred of them on the reef. Ten minutes later, Jerry Allen broke the surface. Treading water next to us, he spit out his regulator, peeled off his mask, and yelled, "We got a new species!"

The unprepossessing prize was a deep-water damselfish species, pure white and one-fourth the size of a business card. Steve, who had surfaced with Jerry, had collected the specimen in the plastic bag that now rested on the skiff's pontoon. We congratulated Jerry and Steve on their discovery.

As we motored back to *Naia*, bouncing off waves, Steve told us he had seen several thousand surgeonfish and over 500 humphead parrotfish—numbers you don't see in most



places anymore. We also found the coral in a wonderful state: 92 species of live coral covered as much as three-fourths of the seafloor at Nikumaroro, and where there was no coral we found healthy coverings of *Halimeda* and Corallinaceae algae, all of which indicated a healthy hard coral reef community.

THREE DAYS LATER we stopped at tiny Rawaki (formerly known as Phoenix Island), which is little more than a pile of coral rock in the heaving ocean. But to a wildlife researcher like Austen it was a paradise, with hundreds of thousands of birds laying their eggs there. It was her job to count this swarming mass of birdlife, including the threatened Phoenix petrel, named after this island, where it was known to breed in the past.

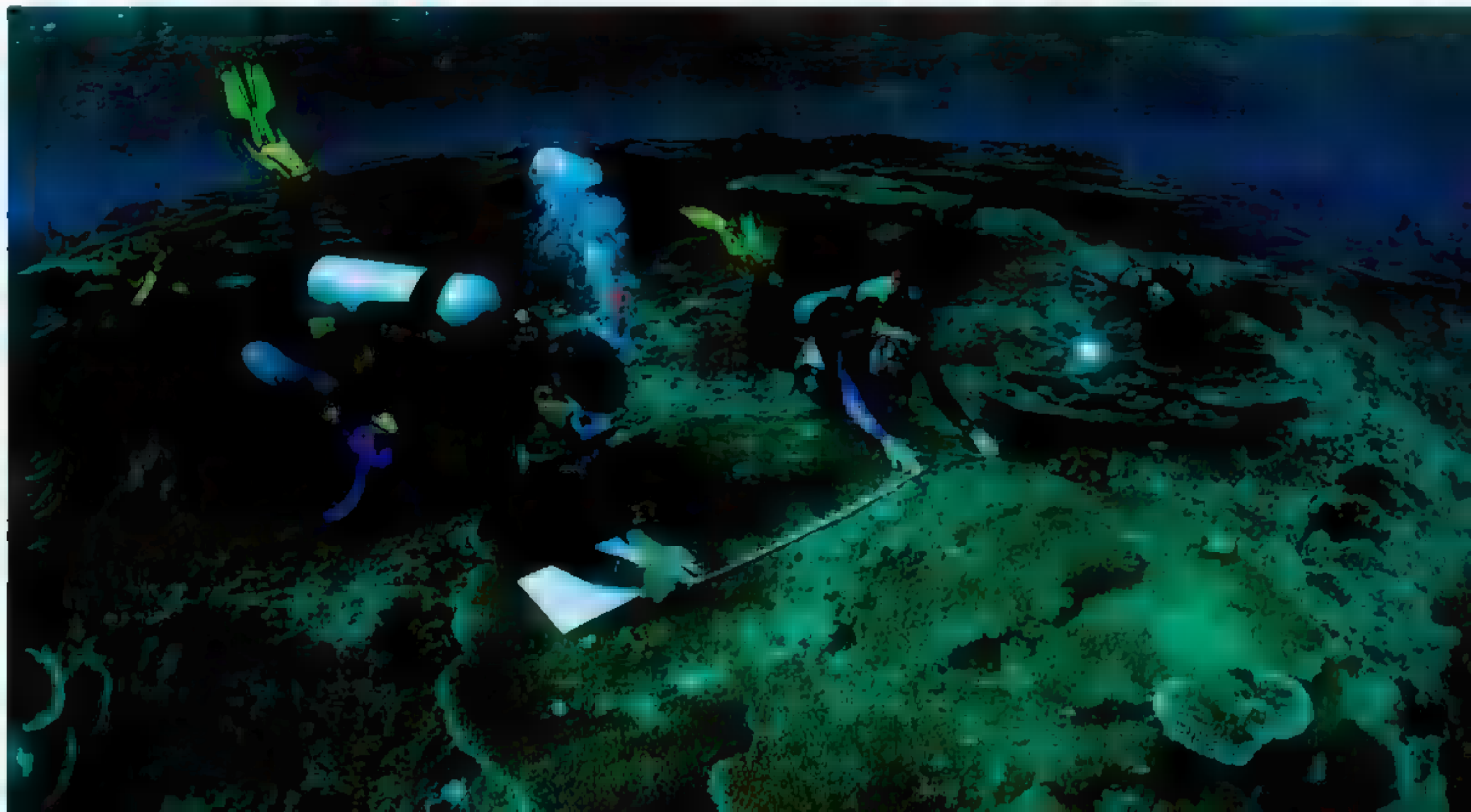
Less than a mile in length and barely 11 feet in height, the island was so small that Rob could find no anchorage for *Naia* and was forced to drift offshore while we did our work. The only way for us to reach the island was to swim from the skiff through surf breaking on coral ledges.

As the skiff nosed between the narrow, propeller-breaking limestone fissures, Austen leaped into the surf, shoes first, fully clothed for protection from the sharp coral. Clutching the gear bag, she started kicking. I followed her lead, and suddenly we were both over our heads, struggling to avoid being gashed on the coral ledges or getting sucked

*To make a biological map of the islands, scientists logged roughly a thousand dives, identifying more than 900 species of coral, fish, and invertebrates, and discovering four new fish species in the process. To survey life below scuba depth, the team lowered a video camera (right) outfitted with bait and timed flashes. In Kanton's lagoon (below), they found delicate table corals flourishing in the absence of anchors and other man-made disturbances.*



HE SPIT OUT HIS REGULATOR, PEELED OFF HIS







## MASK, AND YELLED, "WE GOT A NEW SPECIES!"

beneath them, and trying to avoid sharks.

Each wave hurled us toward the rocks and then dragged us seaward, two steps forward and one step back, until we scrambled ashore, crawling on hands and knees, with only a few bruises and scrapes, and feeling lucky.

"Just your ordinary day of bird-watching!" Austen sputtered, peeling dripping strands of hair from her face and tidying plastered-on clothing.

The birds were all around us—large and small, light and dark, squawking and screeching—and the air reeked of musty guano. To make the most of our time, Austen and I split up, walking in opposite directions around the island, counting birds and sea turtle nests as

we went. With no land predators here except crabs, the terns, frigatebirds, and boobies nested right on the ground, their eggs everywhere. I stepped gingerly through the cacophony of birds, careful not to crush any eggs or disturb downy nestlings or roosting adults.

One red-footed booby watched me with incredulous eyes above a blue beak, its head jutting back and forth as it sat on a hefty egg. White terns hovered inches from my face, impossibly delicate and endearing. Dark wheels of large frigatebirds lazed up and away into the distance.

Eight hours later Austen and I met on the far side of the island, having completed our survey. We were concerned that neither of us





THE AIR IS ALIVE WITH THE FRENZY OF LESSER FRIGATEBIRDS—AND PUNGENT WITH THE SMELL OF THEIR GUANO. RAWAKI ISLAND, A TREELESS

I STEPPED GINGERLY THROUGH THE BIRDS





NUBBIN OF LAND, HOSTS SOME 300,000 SEABIRDS. NINETEENTH-CENTURY SPECULATORS MINED THEIR DROPPINGS FOR FERTILIZER.

CAREFUL NOT TO CRUSH ANY EGGS.





## BARELY ANY PEOPLE LIVE ON THE PHOENIX ARCHIPELAGO. KANTON IS THE ONLY PERMANENTLY INHABITED ISLAND.

had found any Phoenix petrels. But we did identify 13 other bird species nesting or roosting here, some of which fly a hundred miles or more offshore each day to feed. The diversity of species was low, typical of remote islands, but the number of individual birds was high. We counted 150,000 spectacled and sooty terns and more than 50,000 lesser frigatebirds. We also found five nesting sites of green sea turtles, further bolstering the island's ecological importance.

KANTON ISLAND, the largest of the Phoenix group, was our farthest stop. The sun rose early and hot on our first morning there; we were only three degrees south of the Equator now, and the air was thick and hard to breathe. Alistair Hutt, an officer with the New Zealand Department of Conservation, and I took a skiff ashore to talk to the locals.

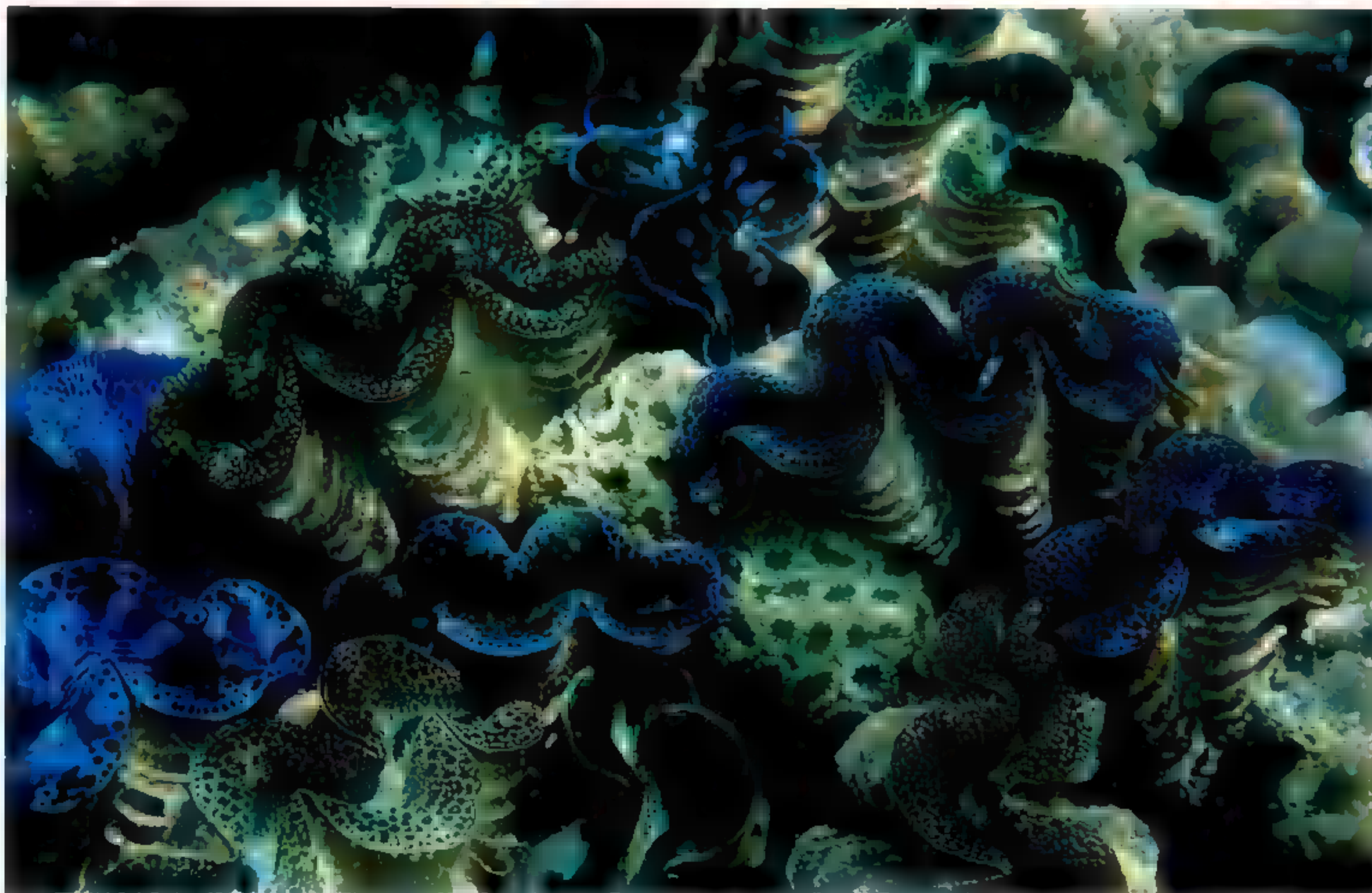
There to meet us, smiling and leaning on his red motorcycle, was Eketi Tokorake, the police officer, customs chief, and all-around guy in charge of the 35 people who live on the

island. Eketi told us about a group of bottle-nose dolphins that live around Kanton—the kind of insular population Alistair had been looking for. Working with the University of Auckland, Alistair hoped to become the first researcher to determine the local dolphins' genetic composition, unraveling the evolutionary history of some of the least studied dolphin groups in the South Pacific. While I stayed with Eketi, Alistair headed out in the skiff and obtained several tissue samples from the dolphins using a tiny biopsy dart.

On his days off, Eketi told me, his time was normally filled by “fishing, resting, and making toddy”—the local drink of fermented coconut sap, collected by climbing up coconut trees and harvesting nectar from flower bud stalks. The year before, however, Eketi had witnessed something unusual.

“A boat came here,” he said, a commercial fishing boat hunting for sharks. The boat had stayed for two months, catching from 30 to 100 sharks a day, he estimated. After visiting several other islands, the boat apparently





*The Kiribati government recruited Titiku (left) and about 150 others to settle on Orona in 2001, but coconut farming and fishing are not proving commercially viable in such a remote location. The island offers few amenities but holds a bounty of natural treasures like shimmering giant clams (above), hand-size gems prized by both seafood and aquarium dealers.*

broke down, returning to Samoa for repairs.

Our dives at Kanton soon proved Eketi's report disturbingly accurate. We found far fewer sharks this year than we had seen two years earlier. Most of the other reef animals—like the spawning parrotfish we saw in the lagoon—were still there, but the absence of the sharks made the reefs seem quieter and less complete. Without the sharks, moreover, the population of bohar, a kind of snapper, had grown significantly larger.

Shark populations don't bounce back quickly. Unlike most fish, which produce thousands of eggs, the local shark species give birth to only a few live young each year. So even if the coral and other fish populations remain untouched and intact, it will take many years for Kanton to regain its sharks.

HAVING COMPLETED our survey of life in and around the islands, we pulled anchor and headed back toward Fiji. In about 1,000 dives at 60 sites, we had discovered six new species of coral and fish, identified 130 species of

coral, 518 species of fish, and more than 250 species of invertebrates, collected 28 tissue samples from dolphins, 70 from fish, and 1,400 from invertebrates, surveyed birds, turtle nests, and vegetation, and explored the sea as deep as 3,000 feet with nets and cameras.

But our most valuable discovery was that the Phoenix Islands, as an entire coral ecosystem, have survived largely intact, making them one of the last havens of ocean wilderness. The world's seas are the key to global survival: They moderate climate, provide food, and generate a significant amount of the oxygen we consume. Sadly, damaged reefs now dominate tropical waters. What we learned in the Phoenix Islands, therefore, may be invaluable to help us understand and even diagnose degraded coral reef systems elsewhere. And that makes it more important than ever to save such primal ocean hideaways.

**WEBSITE EXCLUSIVE** Read photographer Paul Nicklen's field notes to find out why island bunnies hang out with boobies and brown noddies at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).





"IT'S RARE TO SEE SO MANY ANEMONEFISH IN ONE PLACE," SAYS BIOLOGIST JERRY ALLEN OF THIS GROUP ON A MANRA REEF. "THE PHOENIX

WE MUST SAVE SUCH PLACES BECAUSE THE





ISLANDS ARE LIKE A TIME CAPSULE. THEY ALLOW US TO SEE WHAT OTHER REEF SYSTEMS MIGHT HAVE LOOKED LIKE BEFORE MAN INTERVENED.\*

OCEANS ARE KEY TO GLOBAL SURVIVAL. □



*A blindfold calms a packhorse as it's loaded with gear and supplies for a month-long archaeological expedition. The goal: Inca ruins in Peru's daunting Vilcabamba mountains.*

mystery  
mountain  
of the

# Inca

A team of archaeologists saddles up to






explore a lost Inca outpost in Peru.









# The mules had that mean glint in their eyes.

*After two days on steep trails, the 21-member team gets a tantalizing view of the destination, 12,746-foot Cerro Victoria, through a sheer-walled gap, far left. Three more days of zigzagging along rocky paths still lie ahead.*



**A**s our horses climbed the steep, dusty trail, I wondered who was weariest, the humans or the animals. The horses were stumbling on the slippery rocks and the mules had that mean glint in their eyes—but then, so did we. When photographer Gordon Wiltsie's horse gave a shuddering sigh and actually laid down beneath him, I decided it was the animals. We had footslogged three days, sometimes leading our mounts, sometimes riding, to get to this remote valley in the Vilcabamba mountains of southern Peru. Plodding in a long, unruly train of mules and horses—42 pack and 9 saddle—our animals had bolted, strayed, and sometimes thrown us, but we needed them. They were carrying enough gear and supplies to last us a month in the field.

Nine of us—archaeologists, explorers, journalists, and a cartographer—had started our journey in Cusco, the old Inca capital. We were joined at the small town of Huancacalle by a dozen wranglers and their animals, who would help us reach our goal, Cerro Victoria, a 12,746-foot peak in the southern Vilcabamba Range, where in 2001 our team had found a previously unknown Inca settlement, Qoriwayrachina.

Remnants of the settlement, whose name is Quechua for “where wind was used to refine gold”—referring to nearby mines—were scattered over 16 square miles of steep slopes. They included the remains of more than 200 structures: circular dwellings, agricultural storehouses,

roads, funeral towers, cemeteries, and ceremonial platforms. Although the ruins lack the grandeur of the lost city of Machu Picchu, 22 miles to the northeast, they raise new questions about the Inca, whose royalty had withdrawn to the Vilcabamba region in 1537 to wage stubborn warfare against the Spanish.

Had Qoriwayrachina been a refuge for followers of Manco Inca and his sons, the last Inca kings? Was it also a supply center, channeling food and precious metals to Choquequirau, the Inca retreat one valley farther south? Was it built by a previous culture in this steep, forbidding place—and if so, why?

Now that we were only a two-day climb from Qoriwayrachina, I felt a keen anticipation as we set up camp outside the village of Yanama. I joined my exploration partner Scott Gorsuch in the big dining tent to plan the work ahead. I was still puzzled by a key question: Where had the water

*A timeworn skull from a looted cemetery is likely from an Inca. But artifacts unearthed nearby suggest that people lived here on Cerro Victoria at least 1,000 years before the Inca. Fragments of a stone-lined aqueduct provide archaeologist Miguel Colque, at far left, and cartographer Madison Roswell the answer to another mystery: Where did residents get water for the outpost now called Qoriwayrachina?*











A pot fragment decorated with a crude face may date from as early as 400 a.d.



A classic Inca pot was among the grave goods found in an intact tomb.



A worn stone blade may have been used as a potter's tool for shaping clay.



Inca shawl pins were likely crafted from locally mined silver.

# the trail to Cerro Victoria



<p><b>1400</b> Pre-Inca cultures such as Moche, Nasca, and Wari thrive in Peru.</p>	<p><b>1438</b> Cusco is rebuilt by Inca emperor.</p>	<p><b>1450</b> Building of Machu Picchu begun.</p>	<p><b>1500</b></p>	<p><b>1532</b> Pizarro marches into Peru.</p>	<p><b>1537</b> Inca ruler withdraws to Vilcabamba region.</p>	<p><b>1572</b> Vilcabamba is invaded. Last Inca ruler is executed by Spanish.</p>
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# Clues to an Inca Outpost

Since the author and a party of trekkers spotted ruins on Cerro Victoria more than four years ago, two seasons of archaeological excavations have yielded evidence of farming, herding, and silver mining here. The settlement, called Qoriwayrachina in the local Quechua language, may have supplied food and raw materials to larger Inca centers, such as Choquequiran and Machu Picchu. With its extraordinary view of the seasonal movements of sun and stars over surrounding peaks, Cerro Victoria likely possessed astronomical as well as spiritual significance.

A pottery face with eyes like coffee beans may be 2,400 years old.



come from to keep Qoriwayrachina alive? A settlement that size couldn't have survived without a lot of water,

**SOCIETY GRANT**  
This Expeditions Council project was supported by your Society membership.

and there were only two tiny springs on the whole mountain. Their source had to be somewhere else. The previous year we had heard reports of an ancient stone channel coming out of Warmicocha, a glacial lake on Marcana, the snow peak east of Qoriwayrachina. The lake was not far from our present camp. I told Scott what I was thinking.

"All right, then, let's split the group tomorrow," he said. "I'll start work at the western mines, and you guys can go chase water."

In the morning Scott pushed ahead to Minas Victoria, the high pass on the east ridge of Cerro Victoria, with Lizbeth Rodriguez and Miguel Colque, two of our team's Peruvian archaeologists, and our wranglers, while I set out for Warmicocha with Ives Béjar, our Peruvian head archaeologist, and cartographer Madison Roswell. Before we got halfway, however, we ran out of trail and began toiling through thigh-high yellow bunchgrass. After climbing 2,800 feet, we found the first encouraging sign of ancient activity in the area—a large rectangular stone-walled platform, with an old looter's pit in the middle.

"This was probably built by the Inca for ceremonies, perhaps for worship of Pumasillo mountain," Ives said. The snowy peaks of the Pumasillo range formed a dazzling white wall across the valley. We had found three other platforms with similarly stunning views at the main sector farther west. The Inca believed the



mountain gods brought them rain and ensured the fertility of their crops and livestock.

When we finally reached Warmicocha, we saw at a glance that there could never have been a water channel leading west out of this lake. Massive moraines blocked the way. This looked bad.

Yet a water channel had to exist. Eagerly, I scanned Marcana's slopes, looking for signs. I could see there was something out there: about half a mile off, a thin filament of stones running horizontally across the rocky slope. Ives waited at Warmicocha while Madison and I scrambled upward again. Soon Madison, slightly ahead of me, stumbled into a set of hidden gullies filled with tumbling water.

"Here it is," he yelled. "Here's the water for your channel."

The mystery was solved. There was a second lake, Suyrucocha, far above us, spilling copious meltwater from the snows of Marcana. Up ahead we located the line of stones, indeed a remnant of the ancient channel, half obliterated by an old landslide. We followed it down the ridgeline the rest of the day, picking up sections all the way to Minas Victoria pass, where we scrambled down the ridge to reach camp before nightfall.

What an astounding engineering achievement: Traversing impossibly difficult terrain, this aqueduct had once carried water almost five miles across high ridgetops from the glacial lake to the sprawling settlement of Qoriwayrachina on an otherwise dry mountain. What was so vital about this place that an ancient people would invest such resources and labor to sustain it?

**T**wo days later I caught up with Scott at our base camp at the site locally known as Corralpata—"corral terrace"—where a cluster of ruined buildings spilled down a sloping shelf. We traded reports over lunch and talked excitedly about our discoveries so far.

During our previous season at Qoriwayrachina, under the guidance of eminent Peruvian archaeologist Alfredo Valencia Zegarra, we had unearthed a great deal of decorated Inca pottery. But there had also been non-Inca surprises, including a large pot that was Inca in form but decorated in a different style. The circular foundations, scores of them, were not typically Inca, either. Nor were the stone-lined underground

cists in which most of the dead were buried. And we had found burial towers in the style of the Colla, a Lake Titicaca tribe conquered by the Inca.

"Virtually everything written about Vilcabamba concerns the Inca," Scott said, "and yet almost nothing is known about the people who lived here before the Inca conquered this area."

A number of historic centers in this region had already been investigated by explorers, beginning with Hiram Bingham in 1911-12. But these sites were clustered to the north. The southern part of the Vilcabamba Range, where Qoriwayrachina is located, is still a place of numerous ruins, few known historical documents, and many questions.

One clue to what drew people to Qoriwayrachina came during the 2001 expedition when a local farmer led Gary Ziegler and Ernesto García, our Peruvian government supervisor, down to Cota Coca, on a small plain on the shadowy floor of the Yanama gorge. There they found Inca-style ruins—stretching the vertical span of the settlement 7,000 feet, from the summit of Cerro Victoria to the gorge at Cota Coca. Given the range of ecosystems that span afforded, the ancients could have grazed llamas and alpacas on high grasslands, while harvesting potatoes and beans in the mid-zone, and corn, avocados, papayas, and coca on the valley floor—all within a day's strenuous walk. To Andean natives, that would have made the site irresistible.

And then there were the mines. Victoria ridge is pockmarked with abandoned mine shafts. A stone-paved roadway, almost certainly Inca, runs right through them, with spur trails leading toward some individual shafts. The mines were worked as late as the 1960s and '70s, which muddied the waters for archaeology, but earlier miners had probably worked there too.

I was beginning to wonder how we'd ever sort it out. It's too complicated, I said to Alfredo. The archaeologist just smiled. "That's what makes it interesting," he replied.

The only residents on Cerro Victoria today are two families of farmers, who had migrated from Yanama about three years before to gain land for their livestock. A few days after our arrival, one of the farmers, Valentín Sacca, took us northwest around the mountain to show us a big pot he had found. We emerged onto a broad, grassy slope strewn with low, broken



walls. Ancient farming terraces had left eroded lines of stones across the contours, and in places potsherds crunched underfoot.

Valentín led us to a stone-walled enclosure, about 90 feet on each side, and showed us a pale, plain vessel about two feet high leaning in a corner. Ives instantly identified its flared shape and broad mouth as a relatively modern style, probably Spanish colonial. It clearly had been removed from its original context, so archaeologically speaking it was not worth much. But it had led us to this unrecorded sector of the sprawling settlement that might tell us more about who lived here.

"This place keeps getting bigger," Scott said.

"It was a llama corral," Ives said of the big enclosure. "See this entrance? It's just the width for a llama to pass through. A modern gate would be wider to take cattle and horses."

This and another large corral we'd found higher on the mountain told us the settlers were pasturing significant numbers of llamas or alpacas—sources of meat and wool and the only beasts of burden the ancient Andeans possessed. The campesinos had no name for this place, so we called it Llamapata—"llama place."

The next day at Corralpata, Lizbeth Rodriguez uncovered a stone-lined cist in a building near our camp. As she removed the soil, the outlines of ceramic objects clustered at the bottom began to appear. There were three, all intact: a smooth, elegant jar, a small, well-made dish, and a rather crude pedestaled cooking pot. They were all unmistakably Inca styles. As Lizbeth brushed the cist clean she found another item, a tiny clay pot, much like the ones Andean people have used for millennia to hold the lime which they dab on a wad of coca leaves before chewing it.

As Ives went to work measuring and photographing the items and their layout, Lizbeth carefully opened another cist, similar to the first, in the opposite corner of the ruin. This one contained decayed bone and two corroded metal pins, the type Inca women wore to fasten their shawls. We assumed they were the usual bronze or copper but later discovered they were silver, the adornments of a higher-ranking individual.

Lizbeth gazed in wonder at what she had revealed: a woman's burial. "This is very special,"

## What had drawn the ancients to live in this lonely place?

she said. "The woman was Inca. But the burial style, the cist, is not Inca. And it's strange there's no skull. Usually the skull is the last to decay."

"The other cist may have held a religious offering to accompany her," said Ives. "The ceramics are kitchen things, female items." We fell silent, contemplating our meeting with this woman from an unfathomable past.

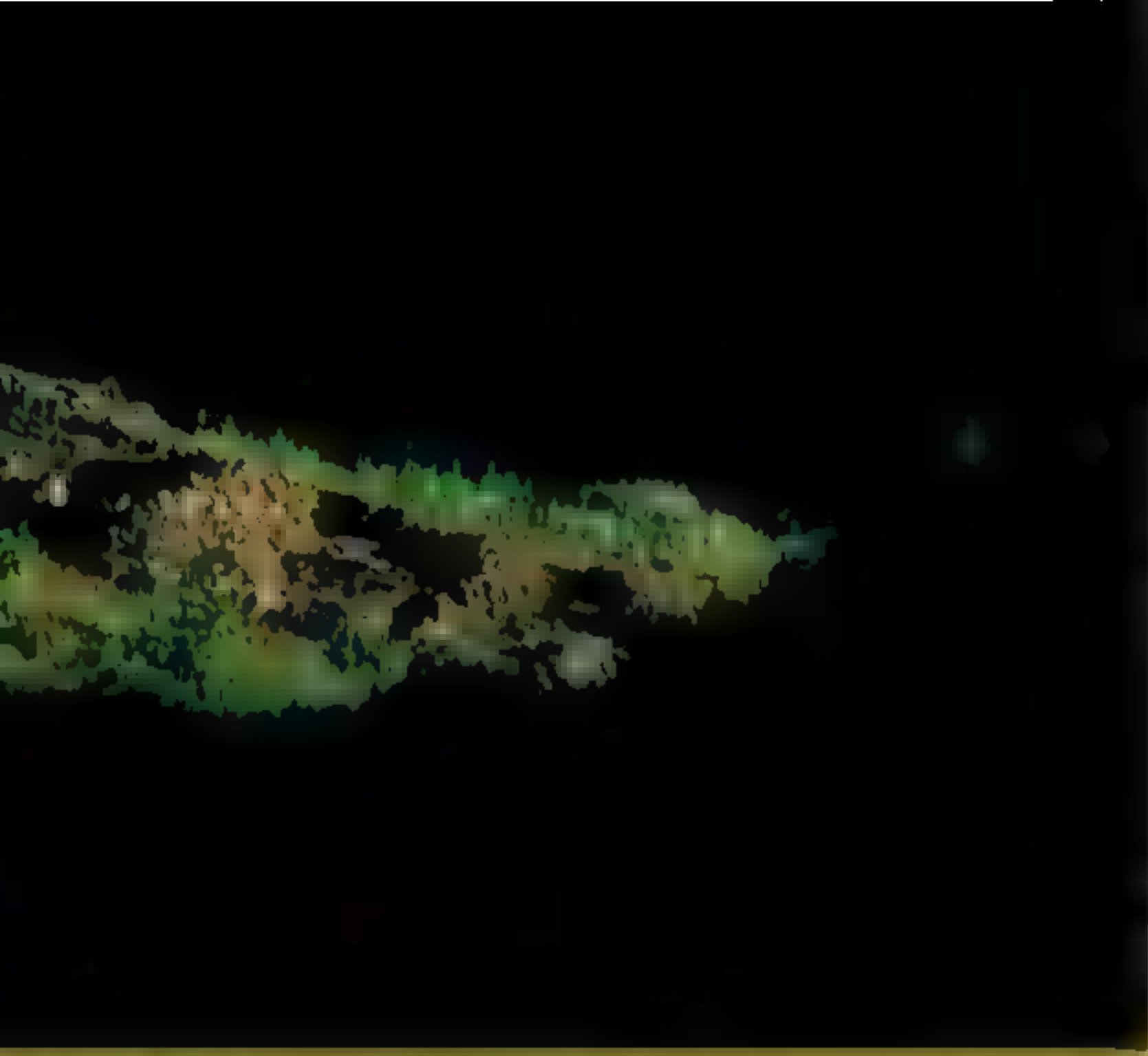
**B**y the end of our second week, Lizbeth was on a roll. One day she emerged from a head-high pit clutching a plain ceramic face with bulging eyes like coffee beans. We circled and pondered. This was certainly like nothing we had seen before, and light-years from Inca style. Ives speculated that the piece came from the Early Intermediate period, from 400 B.C. to A.D. 540, long before the Inca appeared in the Andes. What's more, the eyes were characteristic of the Cusco valley, several days on foot from here—so this region may have been under the valley's influence long before the Inca.

On the last days of our work, Lizbeth and Miguel found yet another ceramic face at Llamapata, more primitive than the first, but again with those telltale eyes. We now had to consider the evidence. We had a mass of local ceramics in a jumble of styles, and the likelihood of a very early occupation. We had radiocarbon analysis that had given us unusually early dates for the Inca period, raising the question: Were pre-imperial "proto-Inca" living here before the Inca founded their empire? If so it would be like finding evidence of 17th-century English settlers in Virginia when the history of those









*Sunset spotlights the expedition's base camp (left) set up on a rare patch of level ground at 10,600 feet. Remains of what may have been an Inca administrative center stand just yards away. To use every possible bit of land, ancient occupants made regular trips from the mountaintop to the Yanama River on the valley floor below. Now, as they did centuries ago, these treks demand stamina and patient maneuvering around other travelers' mule trains (bottom). "No trails in Qoriwayrachina are easy," says photographer Gordon Wiltsie. "It's radically up and down. Nothing is flat."*



settlements had been lost and we only knew about the 19th-century British Empire.

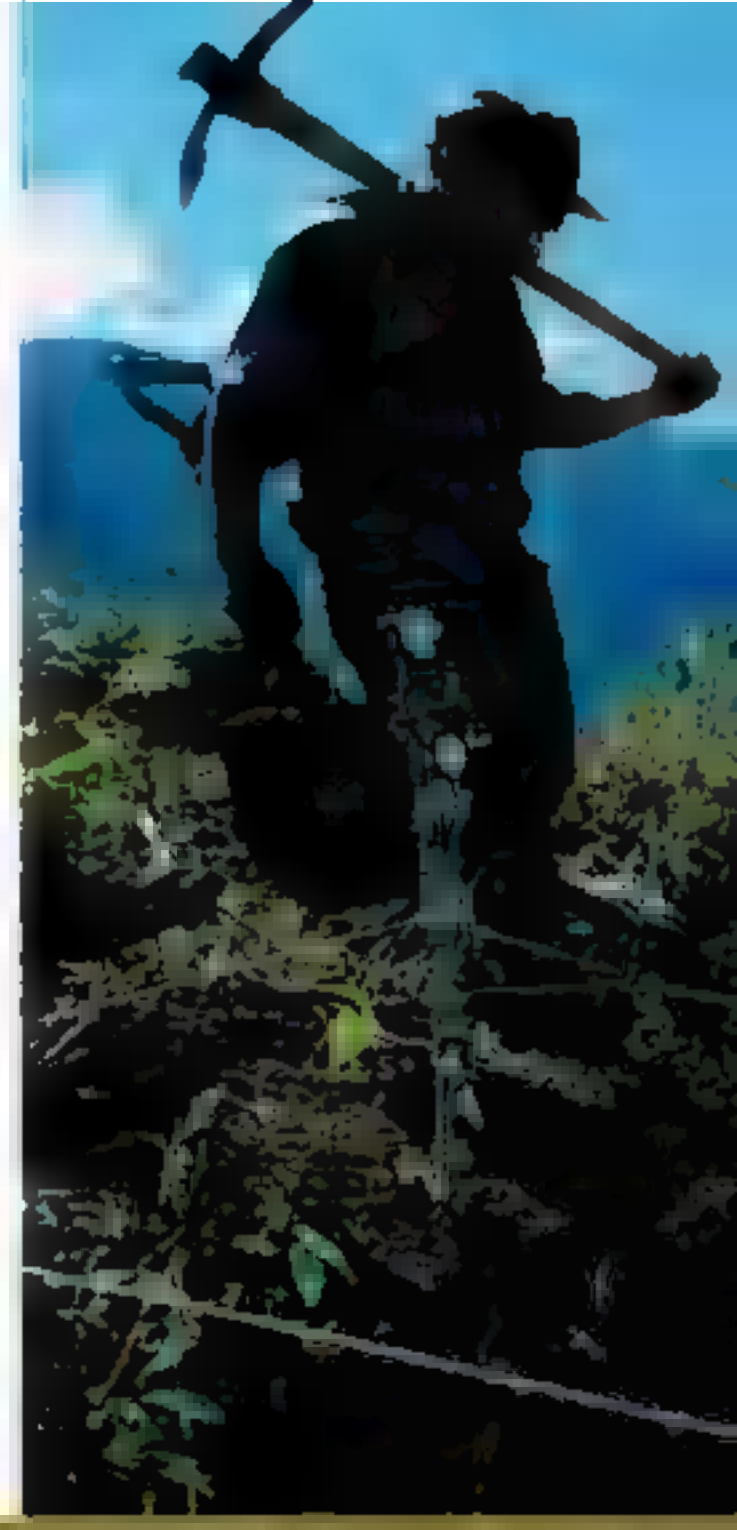
There was little doubt that the Inca had arrived and subjugated whoever lived here. I wondered if those same Inca had held out to the bitter end, through those desperate years before the Spanish overran this last remnant of the empire. Though the idea was plausible, we had so far found no clear traces of the last Inca king or his people. Yet, whether or not Qoriwayrachina had been a refuge for the last Inca king, I felt in my bones that there was more to this site than mining and farming.

What else could have drawn the ancients to live in this lonely place? The question haunted me on a starlit night during our last week on Cerro Victoria, after I'd scrambled up its slippery flanks to camp alone on the summit. It was June 24, just after the winter solstice, when the southern day was shortest and the sun set farthest north on the skyline. Earlier I had watched the setting sun framed perfectly in a U-shaped notch just before it sank below the jagged horizon. Was this significant to the early Andeans, for whom sun and stars were sacred? And where exactly would the sun rise tomorrow?

Cerro Victoria was a grandstand seat for the entire region, a high peak gazing at higher peaks. Facing the brilliant, moonlit cordillera, I contemplated a landscape that Andean people had worshiped for millennia, alive with powerful deities. The ruined platform was surely built here to honor the peaks and the vast horizon with its unbroken panorama of sun, moon, and stars. Perhaps this sacred natural spire represented the essential heart of Qoriwayrachina.

Early light woke me before sunup. An ocean









*Sure-footed pack animals navigate worn and treacherously narrow stone steps that may have been cut into the mountain by the Inca. Quechua-speaking locals (near left) are acclimated to Vilcabamba's high altitude, but the pickax-and-shovel labor of excavation exhausts even the heartiest. As expedition mule drivers gather at the end of a day's work (bottom), firelight etches features inherited from their Andean ancestors. The isolated settlement they're helping to uncover may have played a role in the resistance of the last Inca kings to 16th-century Spanish conquerors.*




of cloud filled the valley below. The sun broke through a brilliant haze over the snowcaps—and as it rose, again it was cupped within a U-shaped notch on the skyline. Behind me Cerro Victoria's shadow fell on the clouds below like a giant arrowhead aimed at a small peaked rise on a ridge to the west. Within days the sunrise and setting points would have moved along the horizon out of those notches, and the shadow would no longer mark that peaked ridge point.

Was I standing in the center of a mighty natural clock, watching the year hand that marked the winter solstice for the ancients at Qoriwayrachina? I felt a glimmer of the awe an Inca might have known, ready to believe it was the mountain deities themselves who marked the farthest points the sun would wander north, and they who designated Cerro Victoria as the observatory.

Our month was over, and it was time for our expedition to leave. Soon the mules would grunt again on the steep mountain trails, this time hauling bags of potsherds instead of supplies. Long weeks of washing, classifying, marking, and analyzing this material would pass before we could say that our work this season was complete. But our immediate concern was the days of punishing trail that lay ahead of us. We loaded the last mule knowing that the story of Qoriwayrachina and its inhabitants was only beginning to be written, and that we surely must return.

**WEBSITE EXCLUSIVE** Watch the explorers and their team in action with video footage from the expedition to the Inca settlement at Qoriwayrachina. • Find a gallery of Web-only photographs from Gordon Wiltsie, and read entries from his field notes at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).

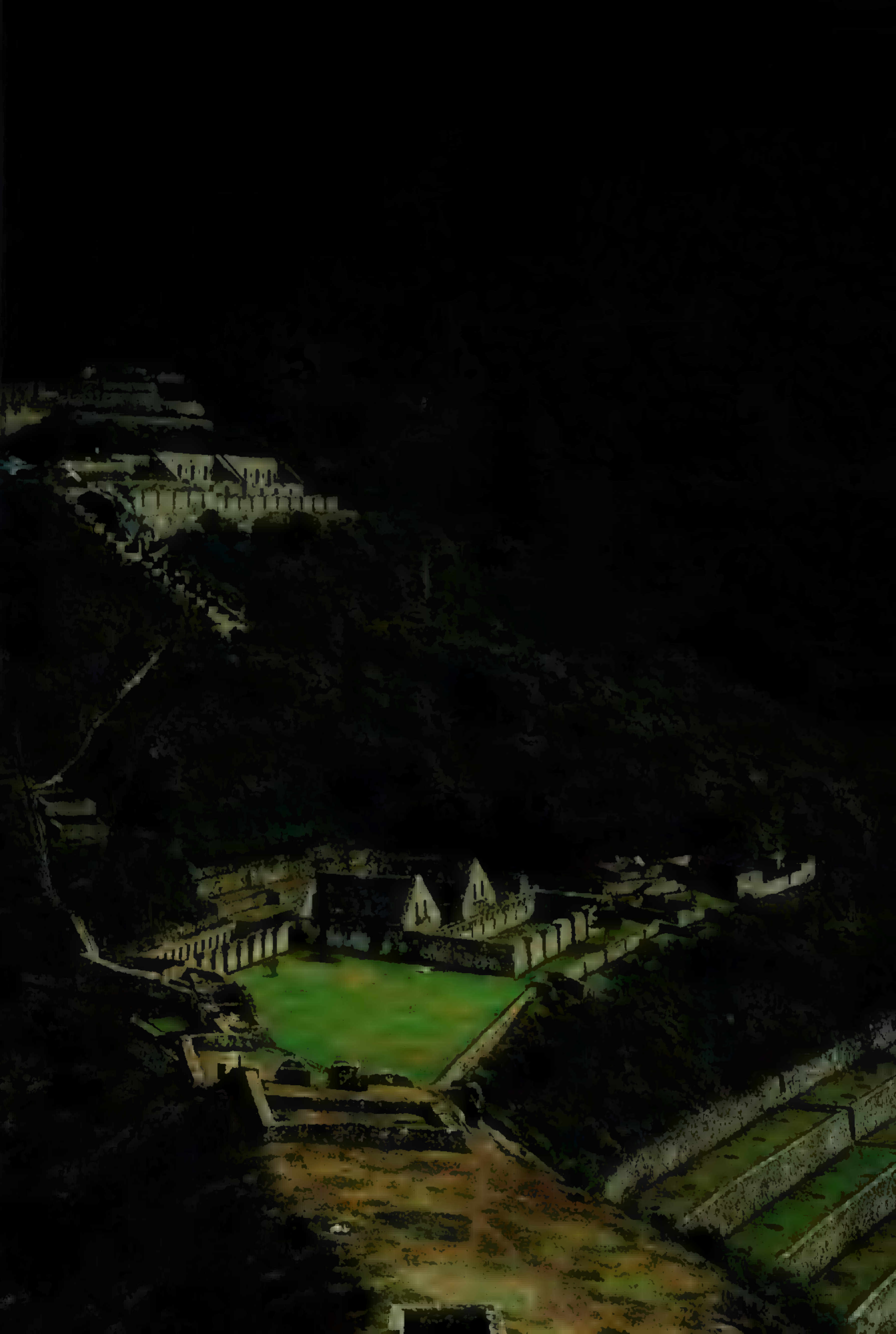




I felt a glimmer  
of the awe an  
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*The Inca center of Choquequirau stands two days' walk from Qoriwayrachina. Did the Vilcabamba settlement merely support royal retreats, or did it have its own importance? Answers long concealed by time and terrain are finally being revealed. □*







NATIONAL  
GEOGRAPHIC  
RESEARCH AND  
EXPLORATION



**GRANTEE**

Lynne Isbell  
Primatologist,  
University

of California, Davis

"Their ability to thrive in a  
dry habitat that's marginal  
for farming is a buffer  
against extinction. But this  
land, too, is being overtaken."

Kenya's  
Patas Monkeys

# Life on a Fast Track

By Lisa Moore LaRoe SENIOR EDITOR

Photographs by Anup and Manoj Shah





Her russet coat matching the arid terrain, a patas mother and her clinging infant lope across a patch of savanna in Kenya's Laikipia Plateau. The world's fastest primates, patas monkeys lead lives full of superlatives—and peril.



# The thief had no idea how to carry the baby, how to hold it. ANUP SHAH

It's tough to get close to patas monkeys. Wily and skittish, they bolt at the sight of humans. The leggy monkeys, clocked at 34 miles an hour, easily eluded primatologist Lynne Isbell when she arrived in Kenya in 1992. "I thought I could keep up on a horse or a bicycle, but trees got in the way," she says. After six months of patient tracking on foot, Isbell was finally able to sit within yards of one patas group that lived on the Laikipia Plateau. And so began a ten-year mission—the longest continuous field study of little-known *Erythrocebus patas*.

As if on a high-speed biological clock, patas monkeys live fast, reproducing at the earliest age of any Old World monkey.

Female patas reach sexual maturity at age two and a half and give birth at three. Babies can survive alone at just six months, though they'll nurse for up to a year. Meanwhile, mothers mate and give birth again, every year. So a patas could be pregnant, nursing a baby, and shepherding a frisky juvenile all at the same time.

As mothers, patas range from doting to cavalier, says Isbell. They routinely hand off very young infants to other females, who babysit while the mother forages. But if an uninvited female comes too close to a baby, the mother will open her mouth (below), a silent threat meaning "keep away."

Only once in Isbell's ten-year study did the social order go

drastically awry. Of eight babies born in 2000, three died from inept handling by females who stole them from their mothers. This followed a period of illness, low birthrates, and high infant mortality, when babies were scarce—and perhaps coveted.

Though patas in captivity have lived past age 20, for adult females in Isbell's group the average age at death was 4, with one-quarter dying each year—a surprisingly high rate. Early reproduction was critical for survival, she says. "They needed to replace themselves."

**WEBSITE EXCLUSIVE** Learn more about patas monkeys from a listing of related websites and a bibliography in Resources at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).







Masked like a bandit, a juvenile female sneaks off with an infant, grasping it awkwardly. Another female, with the white nose of an adult (below), upends a pilfered baby that screams for its mother. Such kidnappings are usually brief and seem to be born more of curiosity than malice. In many cases the babies got safely back to their moms.





# Ranchers love these monkeys. They don't compete with cattle for food.

LYNNE ISBELL



**P**atas thrive on the parched ranches of Laikipia, taking drinks from cattle troughs. The plateau's poor soils support woodlands of whistling thorn acacia trees, chief food source and shelter for the subspecies of patas (*pyrrhonotus*) that Isbell studied. The monkeys eat gum that oozes from the bark and ants that live in the trees' swollen thorns, as well as grasshoppers and other insects flushed from the savanna.

Unlike most primates, which sleep together in trees, patas and their young sleep alone and in a different acacia each night, a habit which may help them elude predators like leopards and domestic dogs.

In circuitous foraging, patas

cover more ground (about four miles a day) over larger home ranges (nearly 10,000 acres) than any primate their size. Adult females—averaging 12 pounds, about half the size of males—direct the action of ■ group, commonly 20 females and their offspring, and one rather peripheral adult male. Isbell's group fell from 51 monkeys at its peak to 7 and now mingles with a neighboring group.

Laikipia supports 300 to 500 patas—likely the largest, most stable population in Kenya. But as Kenya's human population grows, acacias may be toppled for farmland and charcoal. Given their vulnerability to natural fluctuations, patas can't afford any new man-made threats. □

## THE PROJECT

**DATE:** 1992-2002

**PLACE:** LAIKIPIA PLATEAU, CENTRAL KENYA

**GOAL:** TO OBSERVE BEHAVIORS AND ASSESS THE ABUNDANCE AND DISTRIBUTION OF PATAS MONKEYS

### DANGERS TO RESEARCHER:

VENOMOUS SNAKES, ELEPHANTS, FEISTY MALE PATAS

**RANGE OF PATAS:** THREE, PERHAPS FOUR, SUBSPECIES LIVE ■ SAVANNA HABITAT FROM SENEGAL TO ETHIOPIA.

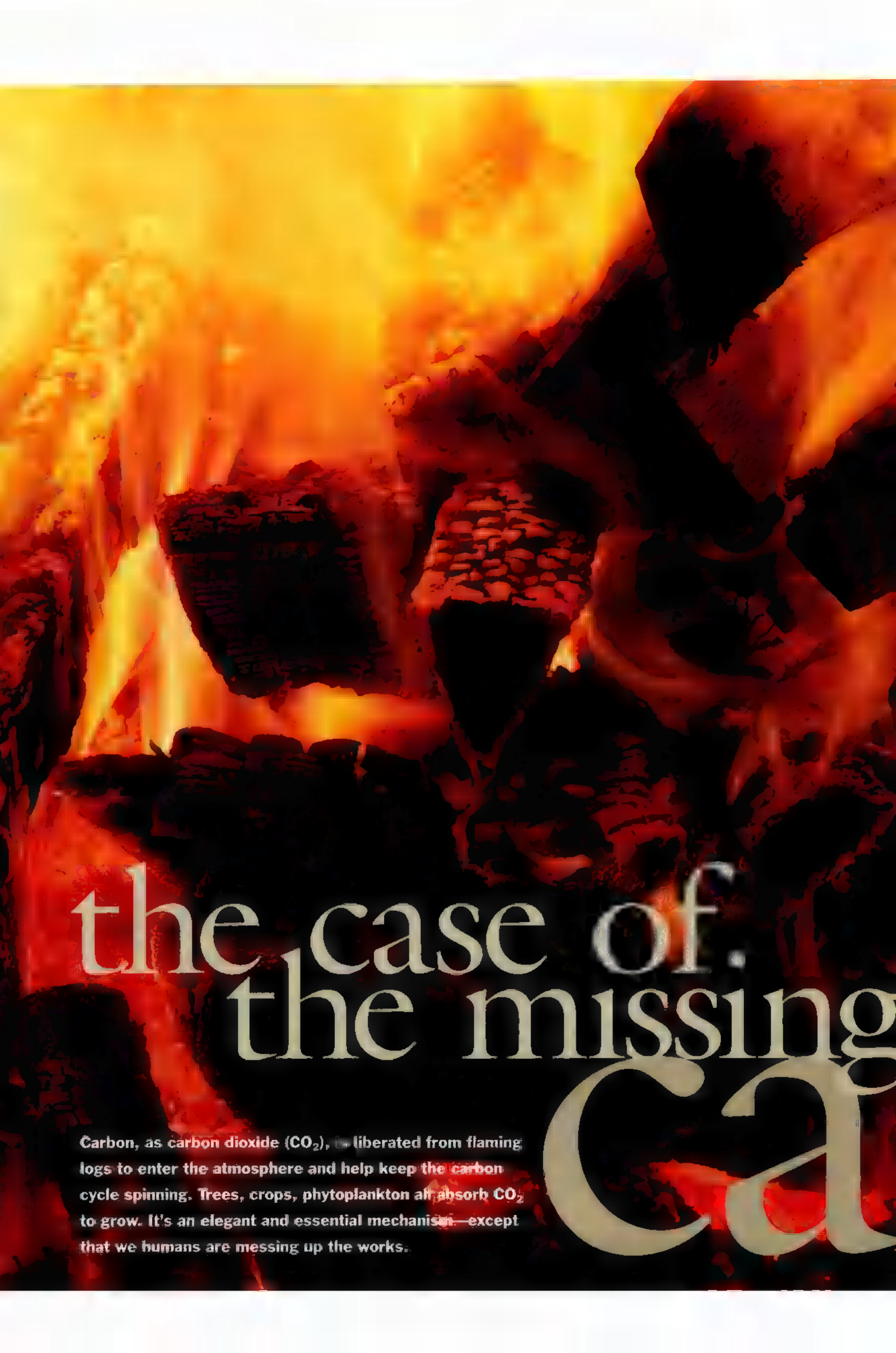
**Young males romp and wrestle during a break in foraging. Stretching for her meal, a mother (right) plucks an acacia thorn swollen black with high-protein ants and larvae. She'll eat and run before the aggressive ants begin to swarm and bite.**












# the case of. the missing Ca

Carbon, as carbon dioxide ( $\text{CO}_2$ ), is liberated from flaming logs to enter the atmosphere and help keep the carbon cycle spinning. Trees, crops, phytoplankton all absorb  $\text{CO}_2$  to grow. It's an elegant and essential mechanism—except that we humans are messing up the works.





Each year humans dump eight billion metric tons of carbon into the Earth's atmosphere. Less than half of it remains there. With the global climate at stake, a burning question arises: Where's the rest of it?

Carbon



Oceans have a mighty appetite







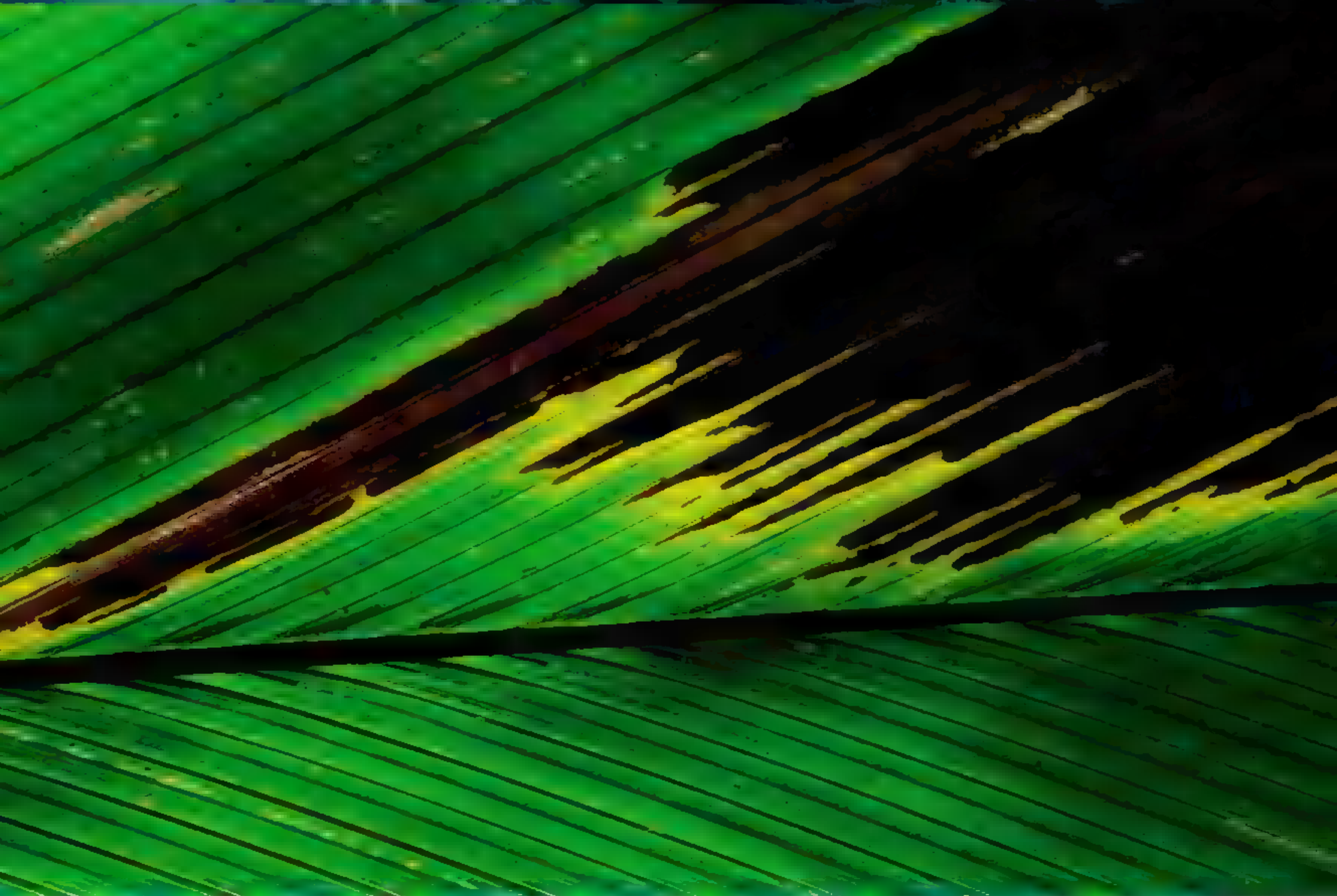
for swallowing carbon dioxide.

Little-known carbon reservoirs—seashells to the layman—pile up on surf-blasted rocks on Florida's Sanibel Island. Oceans act as sinks, soaking up huge amounts of carbon dioxide. A share of that is used by mollusks to build shells that remain long after their occupants die.





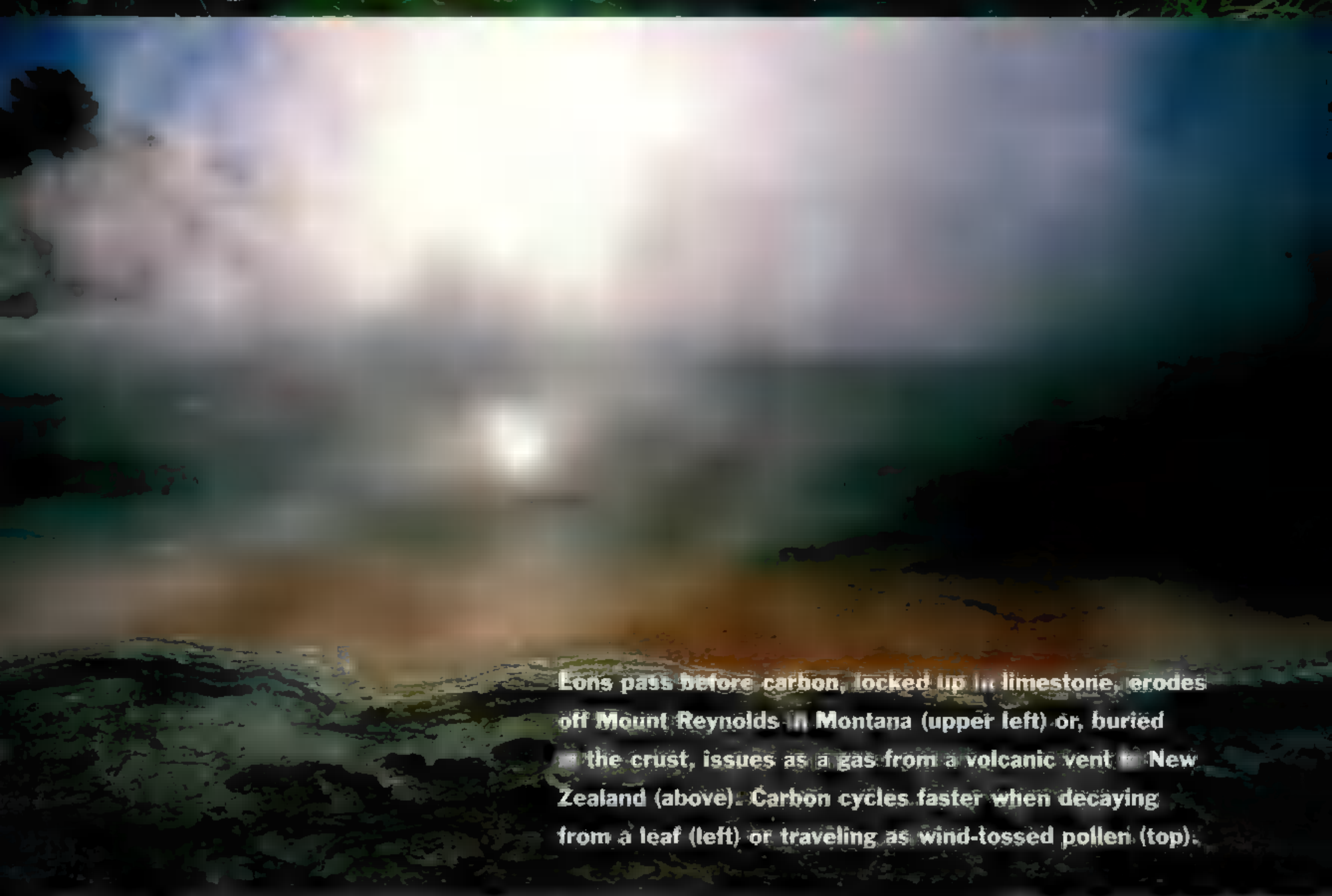
Carbon circulates at speeds ranging







from rapid to infinitesimally slow.



ions pass before carbon, locked up in limestone, erodes off Mount Reynolds in Montana (upper left) or, buried in the crust, issues as a gas from a volcanic vent in New Zealand (above). Carbon cycles faster when decaying from a leaf (left) or traveling as wind-tossed pollen (top).



By Tim Appenzeller  
Photographs by Peter Essick

# It's there on a monitor: the forest is breathing.

Late summer sunlight filters through a canopy of green as Steven Wofsy unlocks a shed in a Massachusetts woodland and enters a room stuffed with equipment and tangled with wires and hoses.

The machinery monitors the vital functions of a small section of Harvard Forest in the center of the state. Bright red numbers dance on a gauge, flickering up and down several times a second. The reading reveals the carbon dioxide concentration just above the treetops near the shed, where instruments on a hundred-foot tower of steel lattice sniff the air. The numbers are running surprisingly low for the beginning of the 21st century: around 360 parts per million, ten less than the global average. That's the trees' doing. Basking in the sunshine, they inhale carbon dioxide and turn it into leaves and wood.

In nourishing itself, this patch of pine, oak, and maple is also undoing a tiny bit of a great global change driven by humanity. Start the car, turn on a light, adjust the thermostat, or do just about anything, and you add carbon dioxide to the atmosphere. If you're an average resident of the United States, your contribution adds up to more than five metric tons of carbon a year.

The coal, oil, and natural gas that drive the industrial world's economy all contain carbon inhaled by plants hundreds of millions of years ago—carbon that now is returning to the atmosphere through smokestacks and exhaust pipes, joining emissions from forest burned to clear land in poorer countries. Carbon dioxide is foremost in an array of gases from human

activity that increase the atmosphere's ability to trap heat. (Methane from cattle, rice fields, and landfills, and the chlorofluorocarbons in some refrigerators and air conditioners are others.) Few scientists doubt that this greenhouse warming of the atmosphere is already taking hold. Melting glaciers, earlier springs, and a steady rise in global average temperature are just some of its harbingers.

By rights it should be worse. Each year humanity dumps roughly 8 billion metric tons of carbon into the atmosphere, 6.5 billion tons from fossil fuels and 1.5 billion from deforestation. But less than half that total, 3.2 billion tons, remains in the atmosphere to warm the planet. Where is the missing carbon? "It's a really major mystery, if you think about it," says Wofsy, an atmospheric scientist at Harvard University. His research site in the Harvard Forest is apparently not the only place where nature is breathing deep and helping save us from ourselves. Forests, grasslands, and the waters of the oceans must be acting as carbon sinks. They steal back roughly half of the carbon dioxide we emit, slowing its buildup in the atmosphere and delaying the effects on climate.

Who can complain? No one, for now. But the problem is that scientists can't be sure that this blessing will last, or whether, as the globe





**Alone in a sealed jar, a mouse would die from exhaled CO<sub>2</sub>. But as scientist Joseph Priestley observed in 1771, adding a mint plant allows the mouse to thrive. In this proof of photosynthesis, the mint absorbed CO<sub>2</sub>, retained carbon for growth, and released oxygen. Two centuries later humans tried—and failed—to survive in a sealed environment in Arizona’s Biosphere 2, background.**

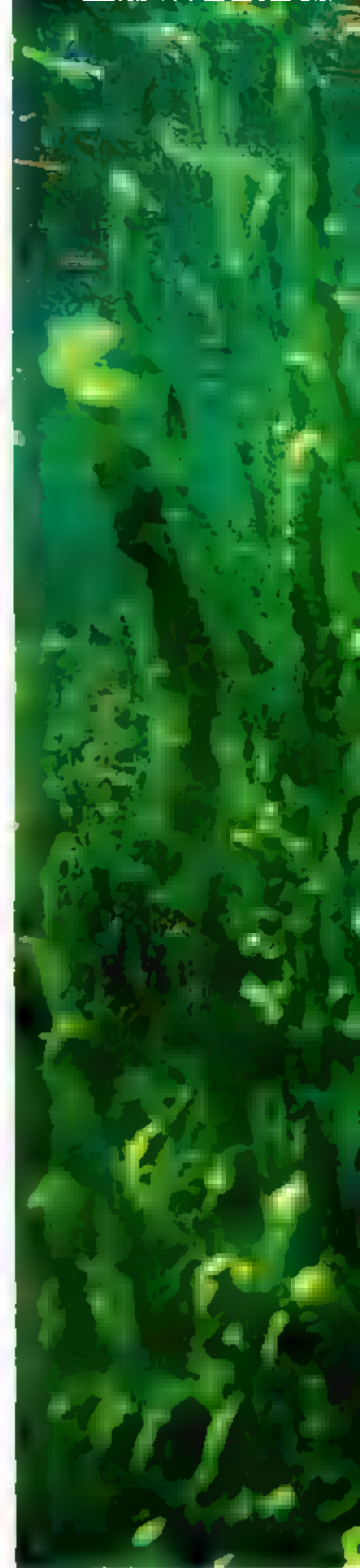
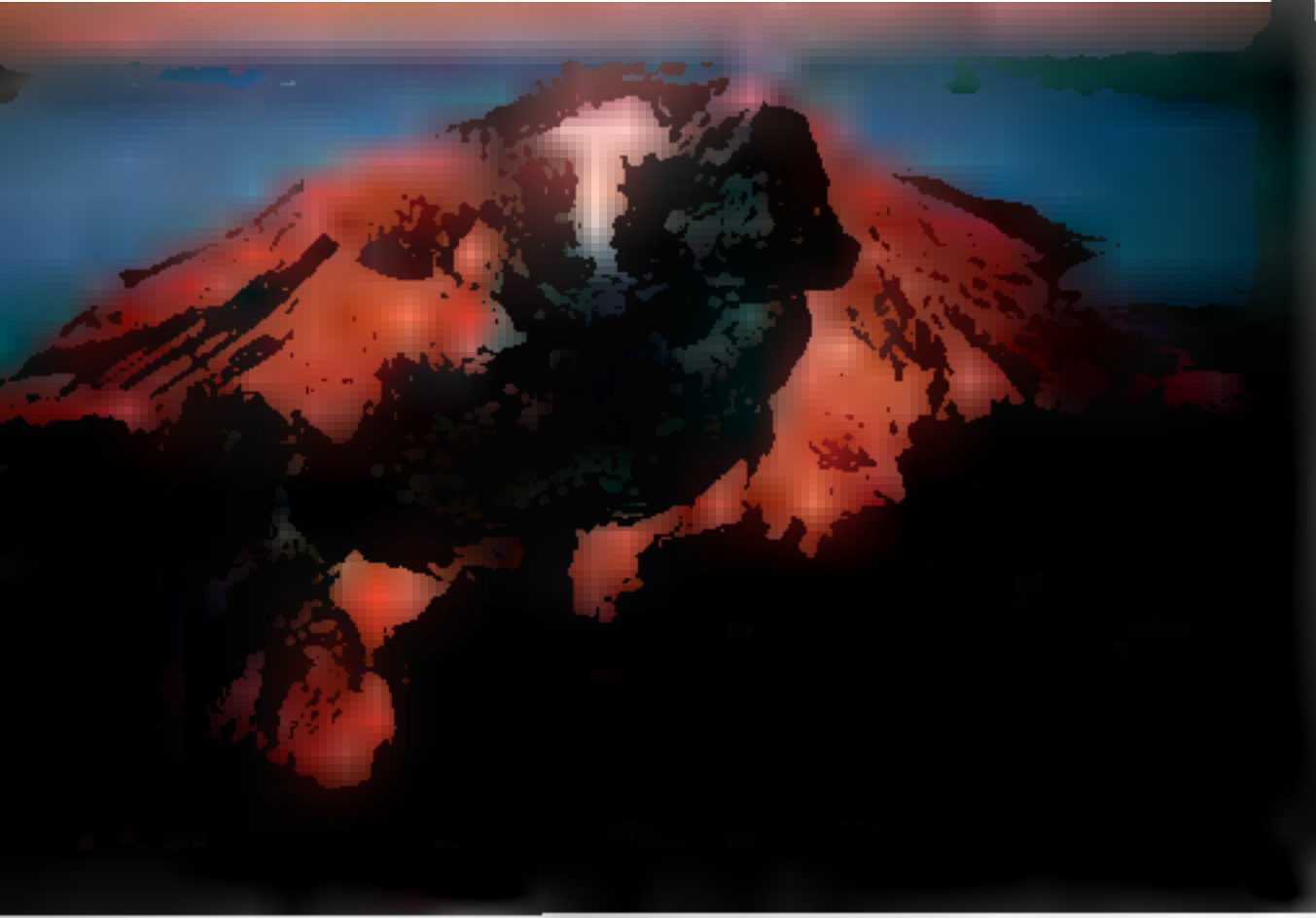
continues to warm, it might even change to a curse if forests and other ecosystems change from carbon sinks to sources, releasing more carbon into the atmosphere than they absorb. The doubts have sent researchers into forests and rangelands, out to the tundra and to sea, to track down and understand the missing carbon.

This is not just a matter of intellectual curiosity. Scorching summers, fiercer storms, altered rainfall patterns, and shifting species—the disappearance of sugar maples from New England, for example—are some of the milder changes that global warming might bring. And humanity is on course to add another 200 to 600 parts per million to atmospheric carbon dioxide by late in the century. At that level, says Princeton University ecologist Steve Pacala, “all kinds of terrible things could happen, and the universe of terrible possibilities is so large that probably some of them will.” Coral reefs could vanish; deserts could spread; currents that ferry heat from the tropics to northern regions could change course, perhaps chilling the British Isles and Scandinavia while the rest of the globe keeps warming.

If nature withdraws its helping hand—if the carbon sinks stop absorbing some of our excess carbon dioxide—we could be facing drastic changes even before 2050, a disaster too swift to avoid. But if the carbon sinks hold out or even grow, we might have extra decades in which to wean the global economy from carbon-emitting energy sources. Some scientists and engineers believe that by understanding natural carbon sinks, we may be able to enhance them or even create our own places to safely jail this threat to global climate.

**The backdrop for these** hopes and fears is a natural cycle as real as your own breathing and as abstract as the numbers on Wofsy’s instruments. In 1771, about the time of the first stirrings of the industrial revolution and its appetite for fossil fuel, an English minister grasped key processes of the natural carbon cycle. In a series of ingenious experiments, Joseph Priestley found that flames and animals’ breath “injure” the air in a sealed jar, making it unwholesome to breathe. But a green sprig of mint, he found,





## The coal, oil, and natural gas that drive the world's economy all contain carbon inhaled by plants hundreds of millions of years ago.

could restore its goodness. Priestley could not name the gases responsible, but we know now that the fire and respiration used up oxygen and gave off carbon dioxide. The mint reversed both processes. Photosynthesis took up the carbon dioxide, converted it into plant tissue, and gave off oxygen as a by-product.

The world is just a bigger jar. Tens of billions of tons of carbon a year pass between land and the atmosphere: given off by living things as they breathe and decay and taken up by green plants, which produce oxygen. A similar traffic in carbon, between marine plants and animals, takes place within the waters of the ocean. And nearly a hundred billion tons of carbon diffuse back and forth between ocean and atmosphere.

Compared with these vast natural exchanges, the few billion tons of carbon that humans contribute to the atmosphere each year seem paltry. Yet like a finger on a balance, our steady contributions are throwing the natural cycle out of whack. The atmosphere's carbon backup is growing: Its carbon dioxide level has risen by some 30 percent since Priestley's time. It may now be higher than it has been in at least 20 million years.

Pieter Tans is one of the scientists trying to figure out why those numbers aren't even worse. At a long, low National Oceanic and Atmospheric Administration (NOAA) laboratory set against pine-clad foothills in Boulder, Colorado, Tans and his colleagues draw conclusions from the subtlest of clues. They measure minute differences in the concentration of carbon dioxide in air samples collected at dozens of points around the globe by weather stations, airplanes, and ships.

These whiffs of air are stacked against a wall in Tans's lab in 2.5-liter glass flasks. Because the churning of the atmosphere spreads carbon

dioxide just about evenly around the planet, concentrations in the bottles don't differ by more than a fraction of a percent. But the differences hold clues to the global pattern of carbon dioxide sources and sinks. Scientists calculate, for example, that carbon dioxide should pile up in the Northern Hemisphere, which has most of the world's cars and industry. But the air samples show a smaller than expected difference from south to north. That means, Tans says, that "there has to be a very large sink of carbon in the Northern Hemisphere."

Other clues in the air samples hint at what that sink is. Both the waters of the ocean and the plants on land steal carbon dioxide from the atmosphere. But they leave different fingerprints behind. Because plants give off oxygen when they absorb carbon dioxide, a plant sink would lead to a corresponding oxygen increase. But when carbon dioxide dissolves in the ocean, no oxygen is added to the atmosphere.

Plants taking in carbon dioxide also change what they leave behind. That's because plants prefer gas that contains carbon 12, a lighter form of the carbon atom. The rejected gas, containing carbon 13, builds up in the atmosphere. The ocean, though, does not discriminate, leaving the carbon ratio unchanged. From these clues, Tans and others have found that while the ocean is soaking up almost half the globe's missing carbon—two billion tons of it—the sink in the Northern Hemisphere appears to be





**Dense algal growth off Canada's Queen Charlotte Islands uses photosynthesis to take up carbon dioxide and release oxygen. Without photosynthesis in the sea, pioneered by organisms called cyanobacteria, Earth's atmosphere would have retained poisonously high levels of CO<sub>2</sub>, spewed over the ages by volcanoes such as White Island in New Zealand (opposite).**

the work of land plants. Their appetite for carbon dioxide surges and ebbs, but they remove, on average, more than two billion tons of carbon a year.

Forests like Wofsy's are one place where it's happening. For more than a decade his group has monitored the carbon dioxide traffic between the trees and the air. Instruments on his tower track air above the treetops as wind and solar heating stir it. As each waft of air passes the tower, sensors measure its carbon dioxide content. The theory is simple, says Wofsy: "If an air parcel going up has less carbon dioxide than an air parcel going down, you have carbon dioxide being deposited onto the forest."

The amount changes fast. "Sunshine, perhaps the temperature, rainfall over the past week—

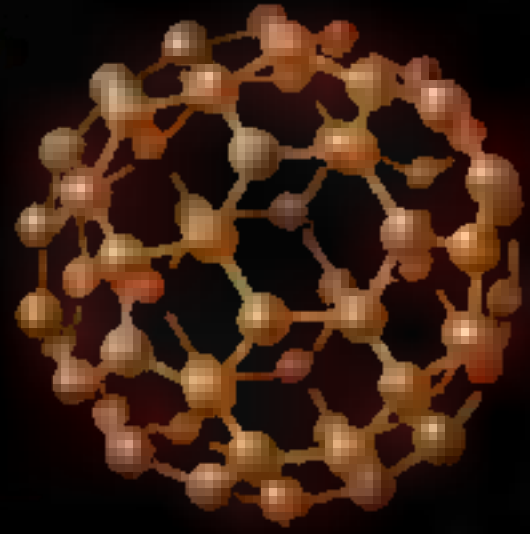
all those factors affect what the forest does on an hour-to-hour basis," he says. Even a passing cloud can dampen photosynthesis, spoiling the trees' appetite for carbon. In winter, when leaves fall and decay, more carbon dioxide—a by-product of plant respiration and decomposition—seeps back out of the forest and into the atmosphere. Still, over more than ten years, the bottom line of billions of measurements has been positive. On balance, Harvard Forest is sieving carbon from the atmosphere.

It shows in the trees and on the forest floor. To check that their high-tech air measurements weren't somehow being fooled, Wofsy's group strapped calibrated steel bands around trees to measure their growth, gathered and weighed deadfall, and set up *(Continued on page 104)*



# The carbon cycle

## A DELICATE BALANCING ACT FOR LIFE'S VITAL ELEMENT



Other than the flow of water, no mechanism in nature is more crucial than the circulation of carbon between air, land, and water. Only four forms of pure carbon are known—diamond, graphite, amorphous carbon (such as charcoal and soot), and fullerene, the molecule at left. Yet carbon's ability to bond with most nonmetals has made it the basis of all organic compounds—plant and animal. Terrestrial vegetation uses 60 billion metric tons of carbon a year to grow—providing oxygen in the process. The demand would exhaust carbon in the atmosphere if not for constant replenishment through plant respiration and decomposition of organic matter. In its complex, finely calibrated gearing, the carbon cycle sustains life on Earth.

### WHAT PART IS CARBON?

Diamond	100%	Limestone	12%
Graphite	100	Agricultural soil	1-2
Coal (anthracite)	92	Steel	0.2 - 1.5
Oil	86		.015
Wood	50	Seawater	.0025
PVC	38	Concrete	
Human body	18	Quartz	

### HUMAN MONKEY WRENCH

The smooth meshing of the carbon cycle's many parts depends on large quantities of carbon being withdrawn from the atmosphere and stored in forests, oceans, and underground deposits of coal, natural gas, and petroleum. Humans have disrupted the cycle, releasing carbon prematurely from these reservoirs—beginning with the burning of forests. The burning of fossil fuels has accelerated the release, flooding the atmosphere with enough carbon dioxide to affect global climate.

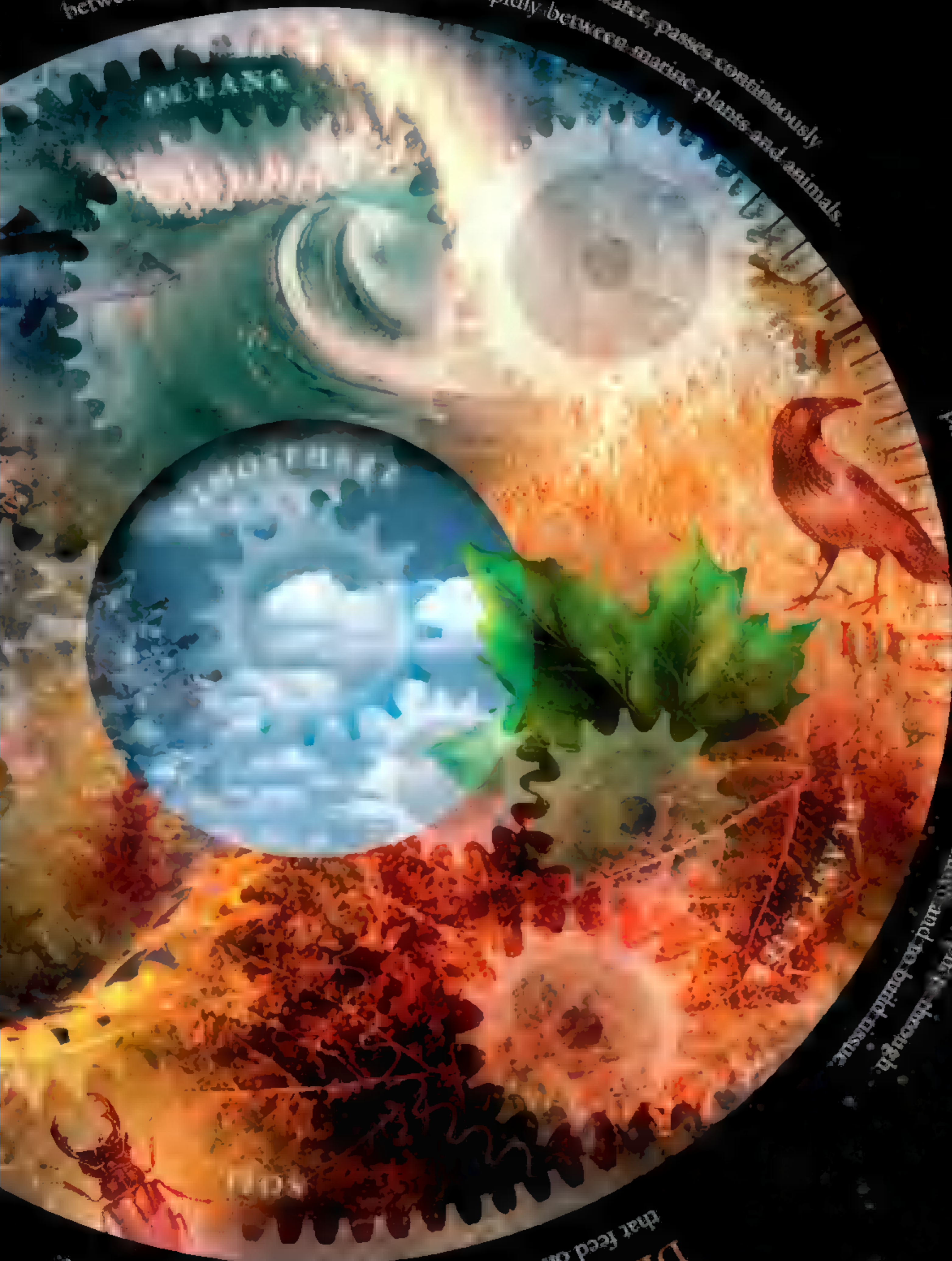
**BURNING** Combustion of fossil fuels and forest fires pumps CO<sub>2</sub> back into the air.

**STOCKING VAS** 100 units of carbon are stored in one of circulation. The 15% locked up in crustal rock, at depths, and coal, oil, and natural gas.



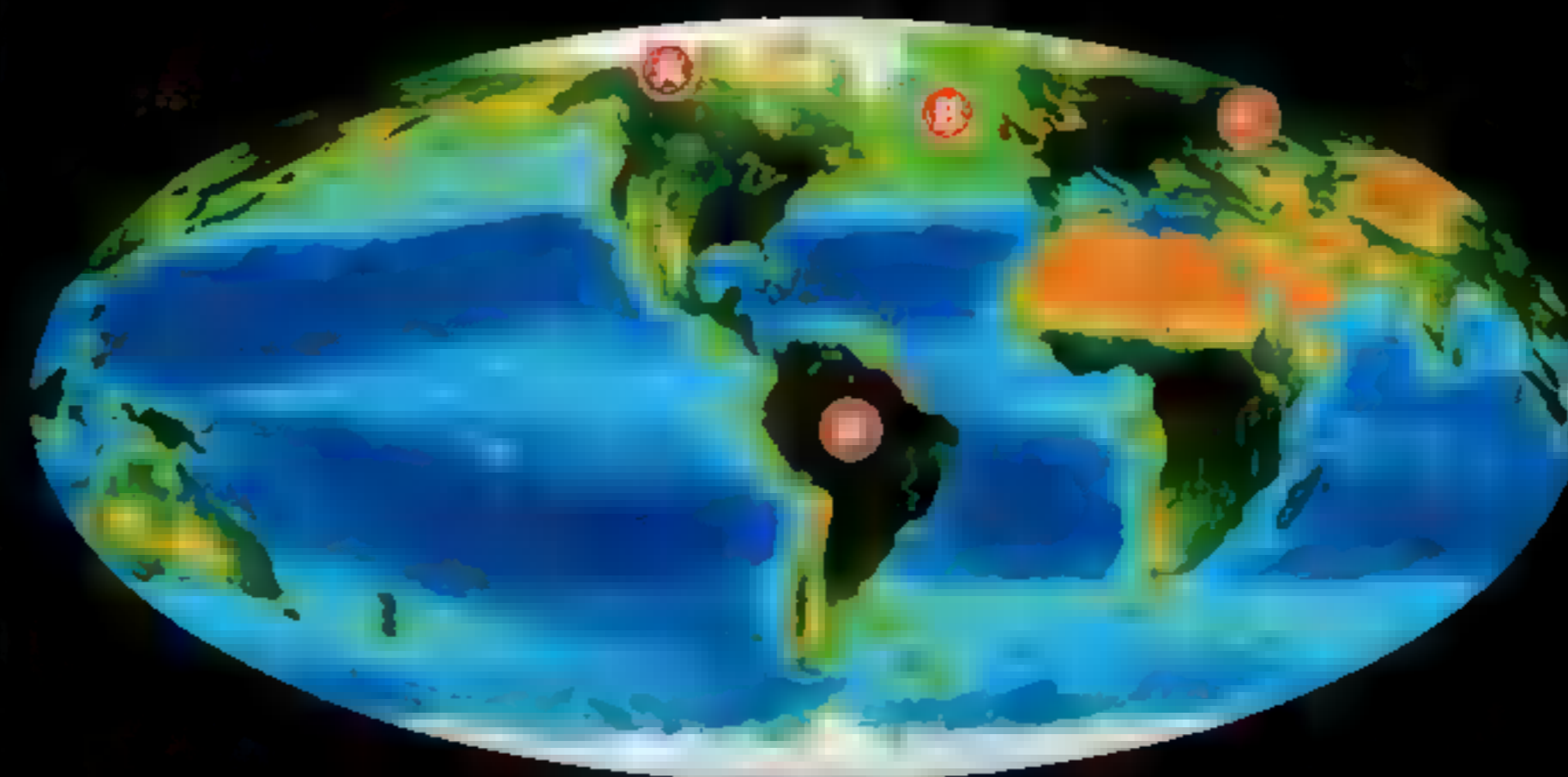


**EXCHANGING** Carbon dioxide, soluble in water, passes continuously between air and sea. Carbon also cycles rapidly between marine plants and animals.



**DECOMPOSING** Respiration by bacteria and fungi that feed on organic matter returns CO<sub>2</sub> to the atmosphere.

**GROWING** Plants absorb CO<sub>2</sub> from the atmosphere through photosynthesis, using carbon and to build tissue.



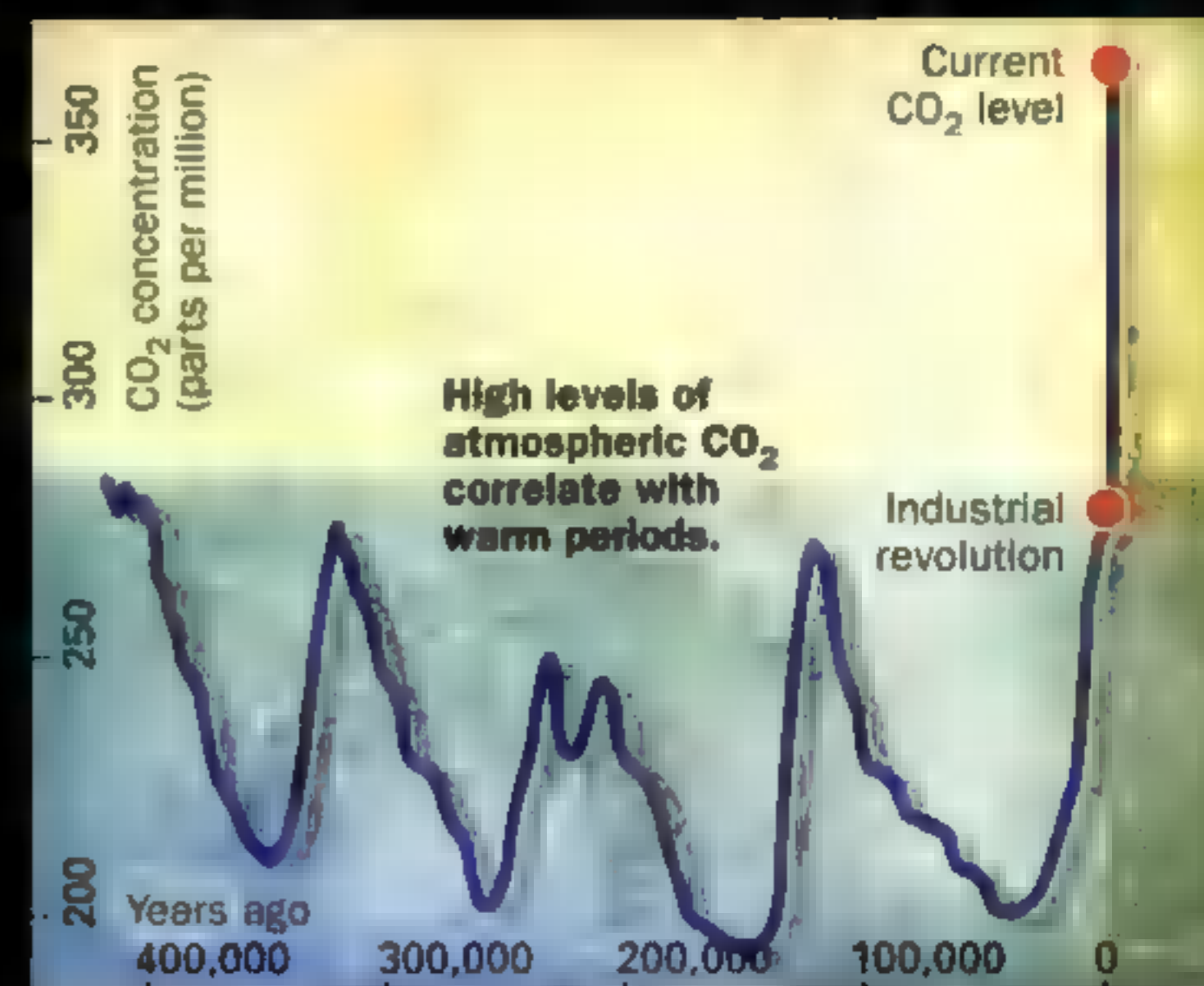
- A Arctic permafrost stores about 14% of the carbon found in the world's soils.
- B North Atlantic carbon uptake equals over 500 million metric tons per year.
- C Boreal forests form Earth's largest soil reservoir of organic carbon.
- D Tropical forests account for about 35% of CO<sub>2</sub> cycled between land and air.

**AN APPETITE FOR CARBON**

Mapping vegetation on land and in the sea pinpoints the most active areas of carbon uptake during the northern spring from March through May. Green regions indicate prolific photosynthesis. From northern boreal woods and tropical rain forests to phytoplankton blooms in the northern Atlantic Ocean, plants remove billions of tons of CO<sub>2</sub> from the air and water. The presence of carbon sinks is vital to moderating the human-made buildup of CO<sub>2</sub> in the atmosphere.

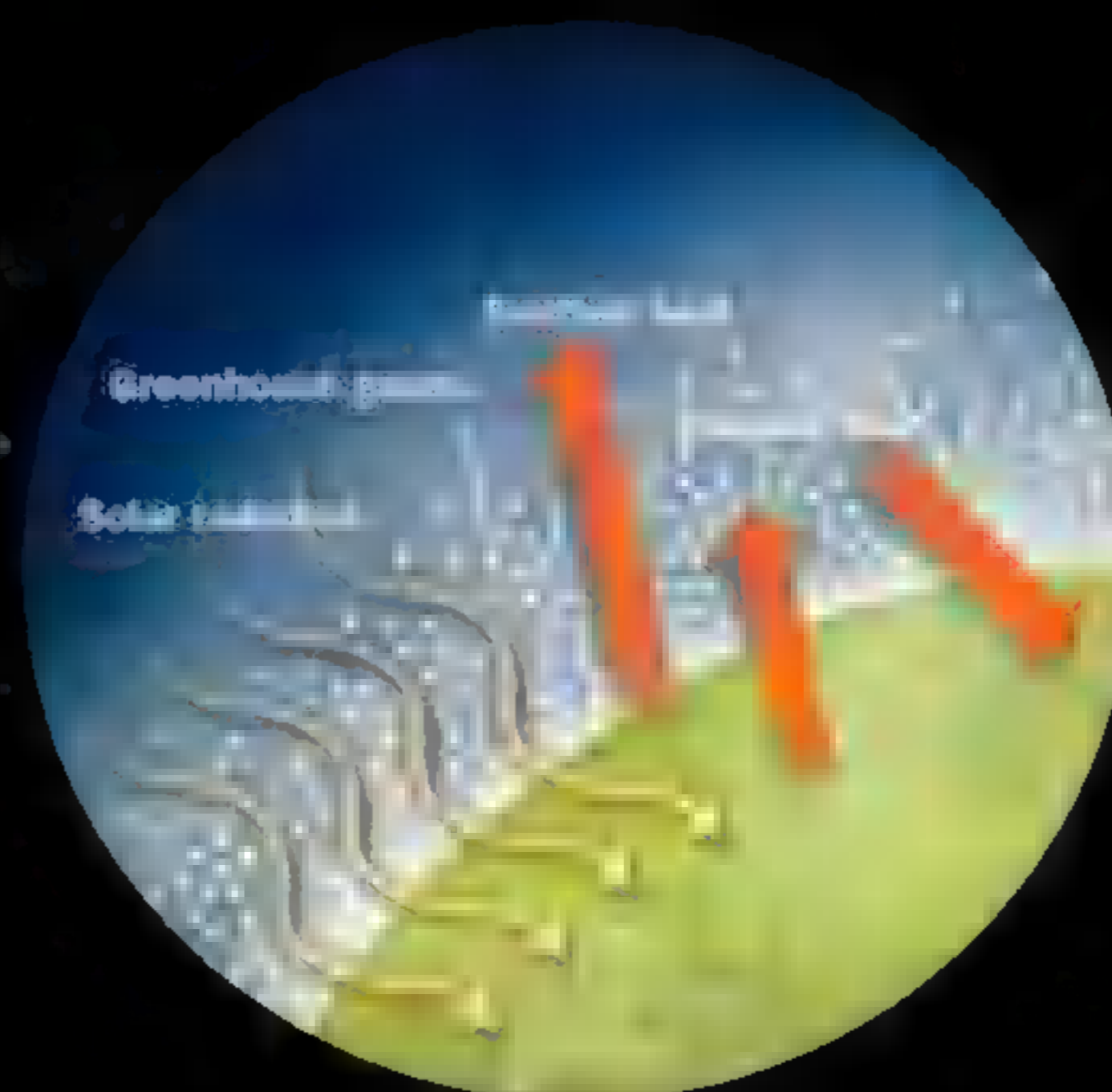
**PRECIPITOUS RISE OF CO<sub>2</sub>**

Major climate shifts of the past 420,000 years—an alternation of ice ages and interglacial periods—never triggered a spike in atmospheric carbon dioxide like the one recorded in the past 150 years. Analyzing air trapped in ice cores from Antarctica, scientists have graphed (right) how the once stable range of CO<sub>2</sub> concentrations ended with the modern era's unprecedented burning of fossil fuels. Atmospheric CO<sub>2</sub> is predicted to rise to two to three times preindustrial levels by 2100.

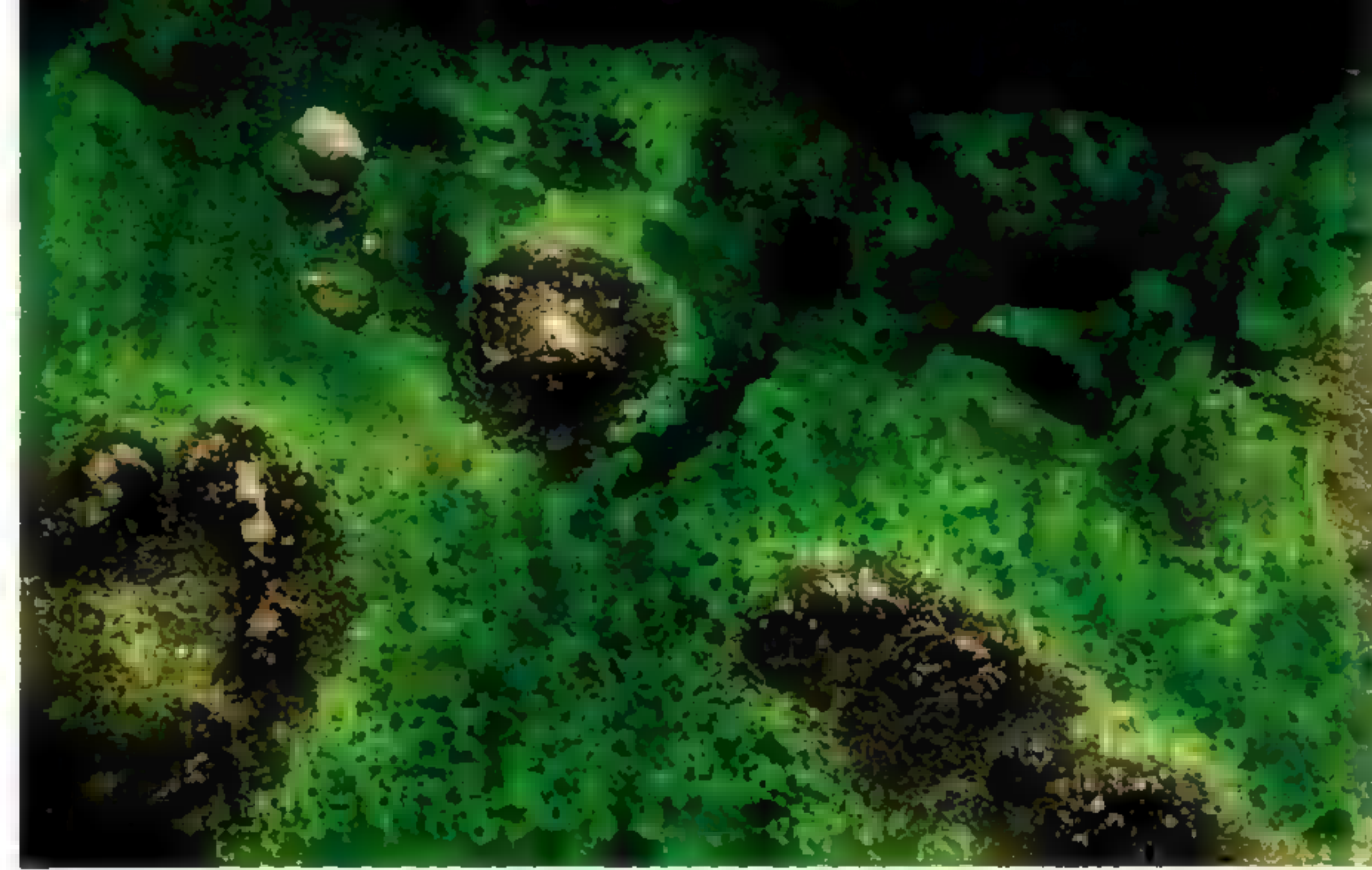
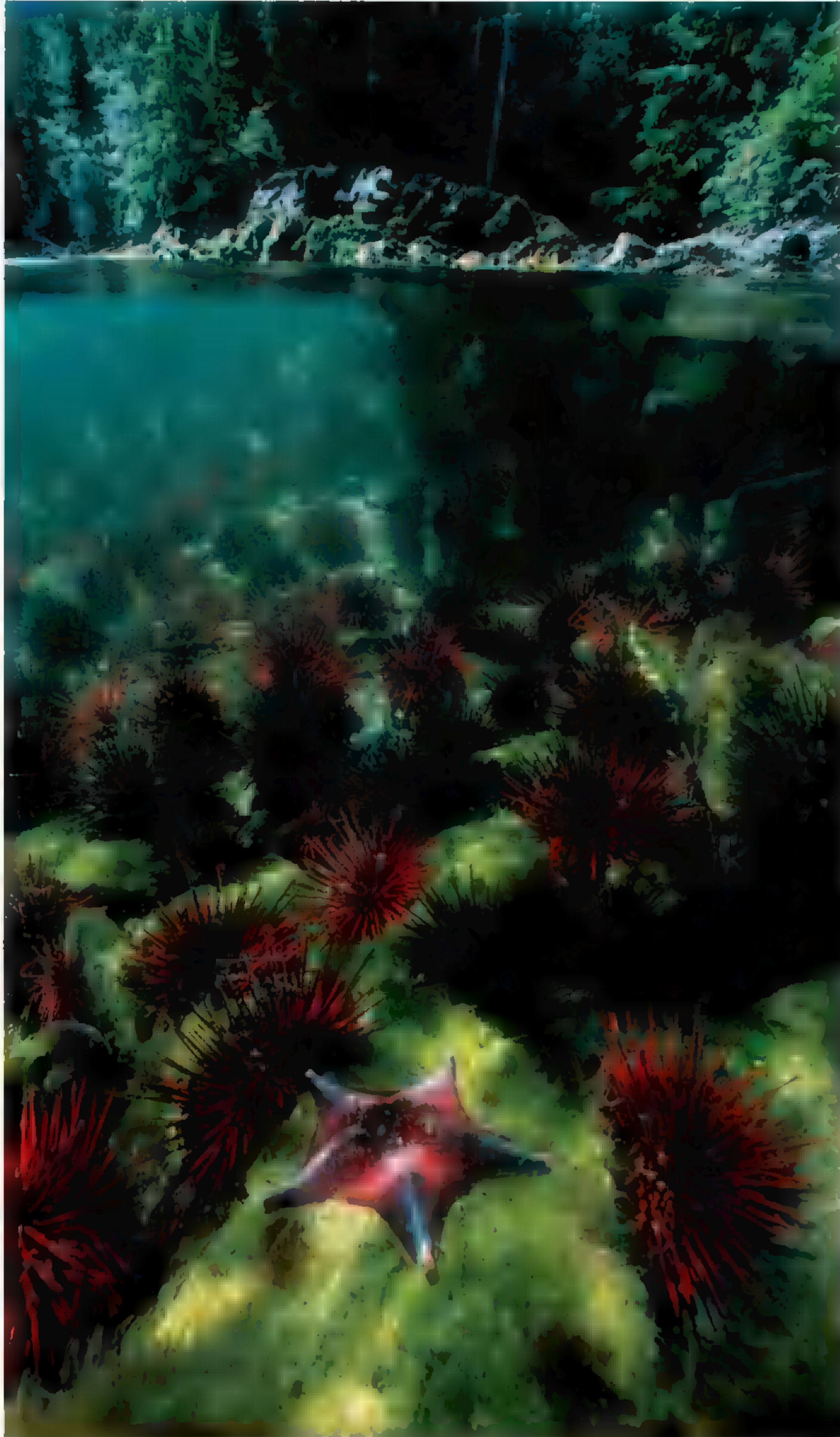


**The greenhouse effect**

Most life on Earth would perish from the cold without an atmosphere to trap heat. A balance of water vapor, CO<sub>2</sub>, methane, and other gases reradiate enough of the sun's heat back to the surface (left), like panes of a greenhouse, to set the average global temperature at 57°F. This natural warming has been aggravated by a 30 percent increase in CO<sub>2</sub> concentrations since the industrial revolution. In the past century the global temperature has risen by one degree—the effects seen in intensifying storms and rising sea levels. Increased greenhouse gas levels, scientists fear, will keep temperatures rising and lead to more damaging climatic changes.







So where is the missing carbon? Oceans and forests are absorbing, at least for now, roughly half of the eight billion tons of carbon that humanity is pouring into the atmosphere each year. Even photosynthesiz-

ing bacteria living in a New Zealand thermal pool do their part absorbing  $\text{CO}_2$  (above). The continued ability of sinks to absorb carbon may vanish if global warming persists. Higher water temperatures would reduce the ability of oceans to dissolve  $\text{CO}_2$ , limiting the carbon available to phytoplankton, the aquatic plants that begin the food chain for creatures ranging from whales to sea urchins (left). Increased odds of drought and fire threaten the health of terrestrial sinks like a cedar forest (right). With rising temperatures, decomposition would quicken, releasing carbon faster from a decaying cow in Brazil (below) and a moldering leaf in an Amazon stream (below right).







If nature withdraws its helping hand, we could be facing drastic changes even before 2050, a disaster too swift to avoid.







## Tens of billions of tons of carbon

a year pass between land and the atmosphere: given off by living things as they breathe and decay.

(Continued from page 97) bins to collect fallen leaves. The idea was to measure just how much carbon-containing wood and other organic matter was building up in the forest, and to see if it matched the gas measurements. It did. Each acre of the forest has been taking roughly three-quarters of a metric ton of carbon out of the atmosphere annually, doing its humble part to counteract greenhouse warming.

Other forests at research sites in the eastern U.S. are putting on weight as well. That's no surprise, Wofsy says. "In the eastern U.S., the most common age for a forest is 40 to 60 years. That's the kind of forest that's going to be growing."

The current Harvard Forest, in fact, has a precise birth date: 1938, when a hurricane barreled in from the Atlantic and leveled earlier stands of trees. Elsewhere in the U.S. humans were the hurricane, clearing vast stands of forest for farming. Abandoned in the early 20th century as agriculture shifted westward to the plains, the land is yielding to forest again. The trees, still young, are getting taller and stouter and putting on denser wood. Year by year this slow alchemy locks up carbon in thousands of square miles of eastern forest.

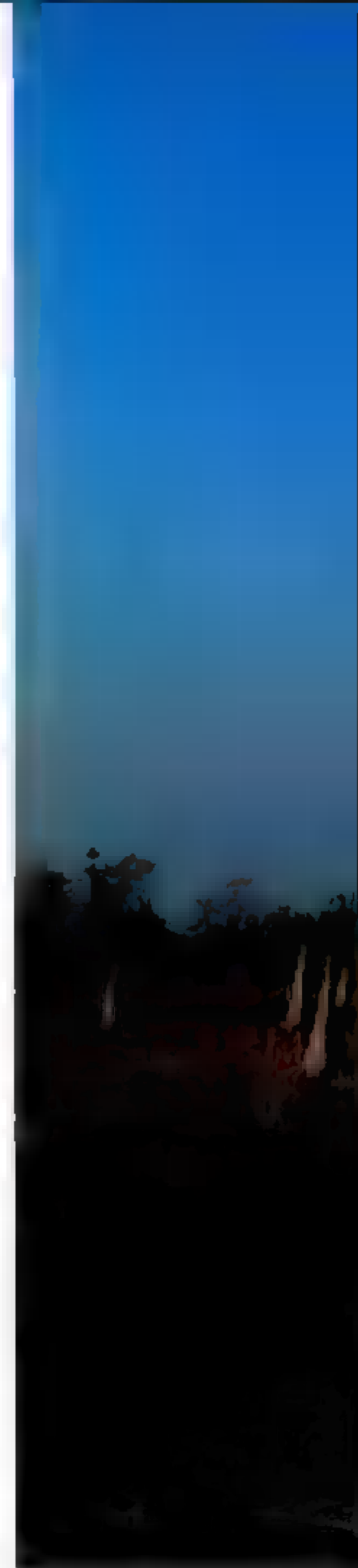
More missing carbon could be hiding in the West. Fire once regularly swept the grasslands, rejuvenating them while killing off woody shrubs like mesquite, juniper, and scrub oak. Decades of firefighting policies called for dousing the smallest blaze and allowed the brush to thrive. The practice disrupted the grasslands' natural cycle and led to bulkier, woodier brush that fueled larger, more destructive fires. But it may also have created a major storehouse for carbon. All told, forest and scrub across the 48 states could be taking in half a billion tons of carbon,

balancing out more than a third of the emissions from U.S. cars and factories. It's a huge gift, says Wofsy: "That's at least four times what they were trying with Kyoto"—the climate treaty that the U.S. refused to ratify—"and it hasn't hurt anyone."

That leaves more than 1.5 billion tons of missing carbon to account for in the Northern Hemisphere. Mature forests, such as tropical rain forest and the great belt of coniferous forest across Alaska and Canada, probably can't help because they're in a steady state, taking in no more carbon dioxide for growth than they give off (plants breathe too). But Europe's managed woodlands, new forests planted in China, and forests regrowing in Siberia after decades of logging could account for another half billion tons, researchers say.

Then there is a change in the far north, where satellite measurements over the past 20 years have shown that vegetation is getting lusher and enjoying a longer growing season. Natives of the North American Arctic report a new luxuriance on the tundra, where once stunted plants, such as dwarf birch, willow, and alder, are growing taller. The reason is simple, says Princeton's Pacala: "You go to the far north, and it's just palpable how much warming there is."

Indeed it is. While the world as a whole has warmed by about one degree Fahrenheit since 1900, parts of Alaska have warmed by five degrees. Brad Griffith studies caribou at the







**Recycling factories of the insect realm, termite nests in Australia exude streams of carbon dioxide as their residents break down plant litter. Termites account for a significant amount of all carbon dioxide released on land through decomposition. Other mighty processors include beetle and fly larvae and leafcutter ants (left), which reduce debris to a size bacteria and fungi can attack.**

University of Alaska Fairbanks, where he has noticed a change in the winters. He remembers clear, cold days and powder snow. “It was never slick, never cloudy; you never had to clean your windshield.” Now the winters are warmer, wetter, and slushier. The shrubs on the North Slope seem to love the change, and Griffith has found that the lush forage gives newborn caribou a better shot at survival.

That’s the good news from the north: Right now global warming, ironically, may be helping forestall even more warming, by speeding the growth of carbon-absorbing trees. But balanced against that are warning signs—hints that northern ecosystems could soon turn against us. Eventually, warming in the far north may have what scientists call a positive feedback effect, in which

warming triggers new floods of carbon dioxide in the atmosphere, driving temperatures higher.

**Worrisome signs begin** on the aircraft approach to Anchorage. As the route skirts the hundred-mile-wide Kenai Peninsula, ugly gray gaps appear in the dark green canopy of spruce below. Since the early 1990s bark beetles have been on the rampage in the Kenai, killing spruce on more than two million acres there. Farther south in the Kenai, says Glenn Juday, a forest ecologist at the University of Alaska, skeletal trees stretch from horizon to horizon. “It’s the largest single area of trees killed by insects in North America,” says Juday. “No outbreak this size has happened in the past 250 years.”

The vast tracts of dead trees will ultimately




Carbon may reside in a bug for a





week and in a mammal for decades.

A close-up photograph of a brown bear's head and paws as it consumes a sockeye salmon. The bear's dark fur is visible on the left and right sides of the frame. Its mouth is open, and its paws are holding the fish. The salmon's bright pink flesh is the central focus, with its white skin and fins visible. The background is a dark, rippling river surface.

A step ahead of bacteria, a brown bear prevents the decomposition of sockeye salmon—dead after spawning—by eating the fish in Alaska's Kulik River. The decay of all animals and plants releases carbon dioxide into the atmosphere.





**Myrtle may look harmless, but she and the 48 million other cows and sheep in New Zealand produce prodigious amounts of methane, a potent carbon-based greenhouse gas. The tube on Myrtle's neck measures methane from a diet of ryegrass, served by nutritional scientist Garry Waghorn. Water-logged rice fields (upper right) rival livestock as a huge producer of methane.**

send their carbon back to the atmosphere when decay or fire consumes them. A warming climate is likely to blame, Juday and others believe. Warmth favors the beetle by speeding up its life cycle and improving its chance of surviving the winter. And as Juday has found in his study area, warming also stresses the hardy northern trees, making them less able to fight off infestation.

Two hundred seventy miles north of the Kenai, on a hillside just west of Fairbanks, the Parks Loop Stand appears to the unschooled eye to be thriving. But Juday, who has worked in this grove of hundred-foot-tall white spruce for 15 years, knows practically every tree's biography—and he is concerned. Heavier, wetter snowfalls have broken off branches and crowns. The trees have also been assaulted by a pest new

to northern Alaska, the spruce budworm.

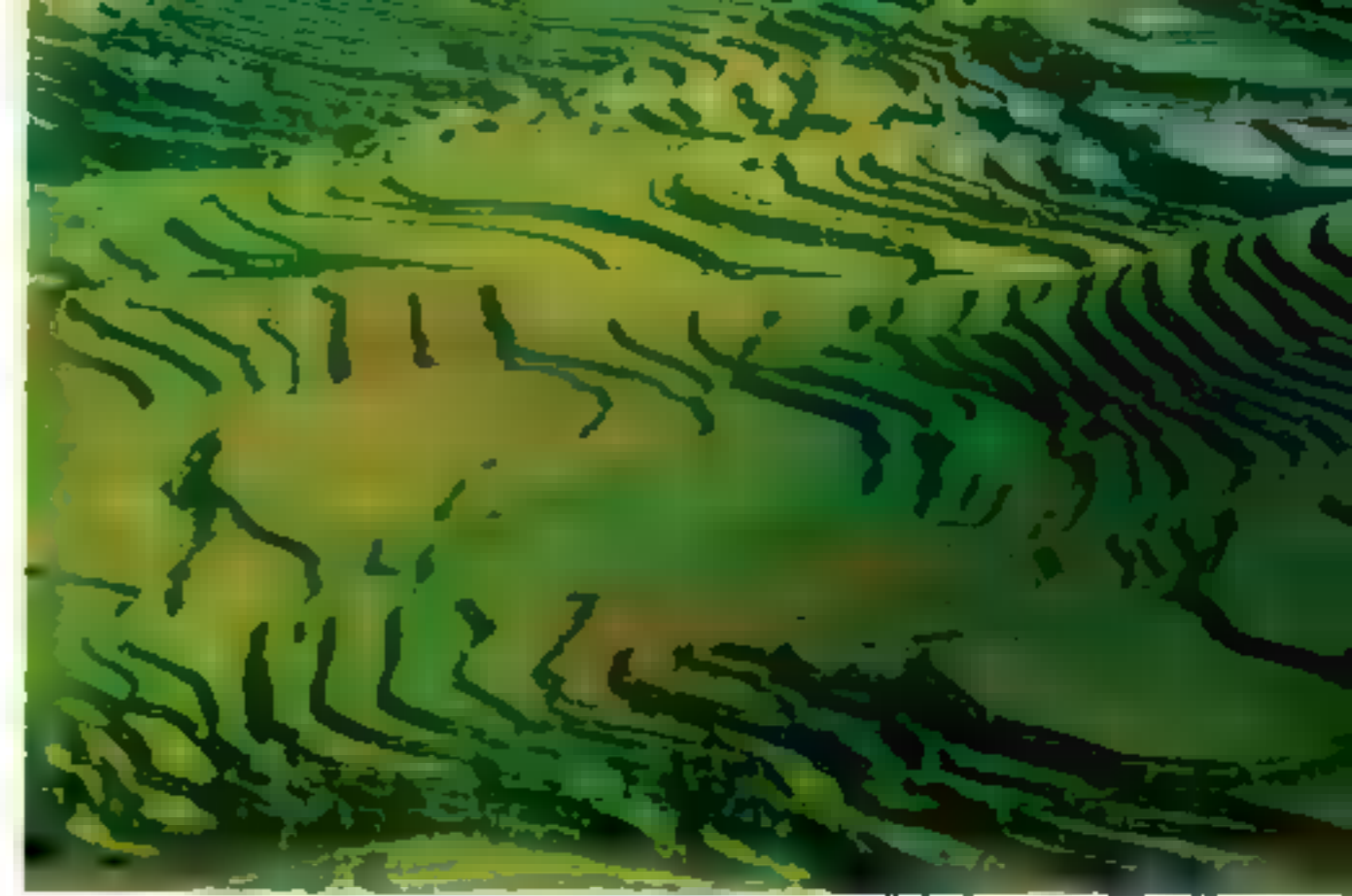
The first outbreak of spruce budworm in this region was recorded in 1989, and Juday thinks the warmer climate is again to blame. Sickly orange branches high in the trees and ragged spruce seedlings festooned with black pupae show that the budworm is still at work. "This was a healthy, beautiful white spruce stand," says Juday. But so many trees have died that the formerly dense canopy has opened up, and the moss that carpeted the shadowy floor has given way to sun-loving grasses.

It's not just the snow and the pests. On the jagged stump of a recently fallen tree Juday points to another fingerprint of warming. The 200-year-old tree's growth rings are thick at the core of the stump, but the outermost rings,





“One-half of the missing carbon is ending up in the ocean,” Takahashi says. That may be as good as it gets.



representing the tree's last few decades of life, are as thin as puff pastry layers. Juday believes the tree's growth has been slowing because of hotter summers. Thin rings are a sign that the trees are undergoing stress, running short of water in the heat.

Since that finding, Juday's group has examined cores from black spruce, another major tree type in interior Alaska. It too grows more slowly in warmer years because of moisture stress. The

future of the northern forest could be bleak. Assuming that Alaska continues to warm at the rate some climate models predict, Juday's analysis points to “zero white-spruce growth” by 2090. If that happened, the boreal forest as we know it would be no more. A smaller carbon storehouse could take its place—perhaps a grassy parkland dotted with aspen groves, Juday suggests. Substantial amounts of carbon dioxide could be released into the atmosphere from the corpse of the old forest.

**Across the far north** a still bigger pulse of greenhouse gas could come from the soil. In a somber grove of black spruce on the broad floodplain of the Tanana River south of Fairbanks, Jamie Hollingsworth, who manages an ecological research site at the University of Alaska, sinks a four-foot steel probe into a damp carpet of moss. It slips in easily at first, then stops abruptly about three feet in. Hollingsworth digs through a foot-thick layer of moss,

roots, and decaying needles, then scoops aside the silty soil below until his shovel grates on the hard permafrost that defeated the probe. Chipping off a clod or two, he reveals silvery veins of ice.

That eternal ice is in jeopardy across much of the far north. Near Fairbanks, at the heart of Alaska, the soil has warmed as much as three degrees Fahrenheit over the past 40 years, putting large tracts of permafrost in danger of thawing. Here and there—even at spots on the university campus—it has already crossed the threshold, and melting has left the ground unstable and boggy. Farther north there's a larger margin of safety.

Fires can speed up the melting. In the summer of 2001 a fire raced through a hundred thousand acres of floodplain forest along the Tanana. The charred snags now stand on bare sand and silt, in many places burned clean of the usual thick moss carpet. The moss is critical to the permafrost: It insulates the soil, keeping it at subfreezing temperatures and helping preserve the ice through the summer. Any permafrost in the fire zone is now in danger of thawing—and hotter summers have made fires more common in many parts of the north, including Siberia and western Canada.

Climate experts keep a worried eye on the permafrost because vast reserves of peat and other carbon-rich organic material are frozen into it—a global trove of carbon estimated at 200 billion tons. For hundreds, perhaps thousands, of years low temperatures entombed it. Now, says Terry Chapin of the University of Alaska, “it's potentially a very large time bomb.”

The permafrost's full megatonnage isn't certain. Some of the subterranean ice would





Smoke means the production of





Land-clearing fires, like a blaze in a Florida sugarcane field (below), provide rapid and spectacular delivery of carbon to the atmosphere. But for sheer volume, nothing compares with a coal-burning power facility like Plant Bowen near Cartersville, Georgia (left). The conversion of fossil fuels into energy accounts for 80 percent of the annual human contribution to CO<sub>2</sub>



emissions, with 60 percent of that coming from industrial nations. In China coal use booms as trucks deliver chunks of it (bottom left) straight from the mine to homes. Land-use changes such as deforestation are responsible for the rest of the CO<sub>2</sub> surge, prompting researcher Chris Doughy (above) to measure how quickly new growth in a logged clearing in the Amazon can absorb carbon and help reverse the massive outflow.

energy—and carbon on the loose.





# Start the car, turn on a light, or do just about anything, and you add carbon dioxide to the atmosphere.

create bogs when it melted, and the oxygen-poor waters of bogs can inhibit decay and keep the carbon locked up. But northern warming could well bring a drier climate, and that could open the way to a worst-case scenario, says NOAA's Tans. "If, due to warming in the Arctic, the permafrost warmed up and dried out, most of that carbon could be released." The atmospheric level of carbon dioxide could jump by a hundred parts per million as a result, he says—more than 25 percent above current levels.

**So where in nature** can we look for salvation? Until recently climate scientists hoped it would come from farther south. In temperate and tropical vegetation, they thought, a negative feedback effect called carbon fertilization might rein in the carbon dioxide rise. Plants need carbon dioxide to grow, and scientists have found that in laboratory chambers well-nourished plants bathed in high-carbon dioxide air show a surge of growth. So out in the real world, it seemed, plants would grow faster and faster as carbon dioxide built up in the atmosphere, stashing more carbon in their stems, trunks, and roots and helping to slow the atmospheric buildup. Such a growth boost could, for example, turn mature tropical forests—which normally don't soak up any more carbon than they give off—into carbon dioxide sponges.

Alas, it appears not to work. At Duke University's forest in North Carolina, William Schlesinger and his colleagues have been giving hundred-foot-wide plots of pines a sniff of the future. Over each plot a ring of towers emits carbon dioxide at just the right rate to keep the concentration in the trees at 565 parts per million, the level the real atmosphere might reach by mid-century. When the experiment started seven years ago, the trees showed an initial pulse of growth.

"These trees woke up to high carbon dioxide and were able to make good with it for a couple of years," says Schlesinger. But then the growth spurt petered out, and the trees' growth has slipped most of the way back to normal. That's

not to say that high carbon dioxide didn't have some long-term effects. Poison ivy, for some reason, "is one of the winners," says Schlesinger, with a sustained growth rate 70 percent faster than normal. And allergy sufferers will not be pleased to learn that the carbon dioxide-fertilized pines produced extravagant amounts of pollen.

To take advantage of a carbon dioxide bonanza, it seems, most plants also need extra nitrogen and other nutrients. Schlesinger's experiment is one of many to show lately that in the real world, more carbon just means plants will probably run short of something else essential. Resurgent forests are soaking up plenty of carbon now, but we owe that mainly to our ax-wielding forebears, who cleared the land in centuries past. That land sink is not likely to increase by much, say scientists. And it will eventually saturate as today's young forests mature. "We can expect this sink to disappear on the order of a hundred years," says Princeton's Pacala. "You can't count on it to keep getting larger, like manna from heaven, the way a carbon-fertilization sink would."

The outlook for an increased ocean sink is no brighter. Taro Takahashi of Columbia University's Lamont-Doherty Earth Observatory has spent decades on oceanographic research ships, making thousands of carbon dioxide measurements just above and just below the water surface to track the exchange of gas between the ocean and the atmosphere.

The North Atlantic and the southern oceans have cold, nutrient-rich waters that welcome carbon dioxide, Takahashi has found. Carbon dioxide dissolves easily in cold water, and the nutrients foster marine-plant growth that quickly uses up the dissolved carbon dioxide. When the plants and the animals that feed on them die and sink into the abyss, their remains carry away the carbon and make room for more.

The traffic mostly goes the other way in warmer, less biologically rich seas. But the global balance is favorable, for now at least. More carbon dioxide dissolves in the oceans than is given off. Takahashi's measurements confirm



that the oceans take up nearly as much carbon as the regrowing forests and thickening brush on land: an average of two billion tons a year. “One-half of the missing carbon is ending up in the ocean,” Takahashi says.

That may be as good as it gets, he adds. “My major question is whether this ratio is going to change” as global warming raises the temperature of surface waters and carbon dioxide continues to build up in the atmosphere. “The prognosis is not particularly bright,” Takahashi says. A warm soda fizzing over the rim of a glass illustrates one effect: carbon dioxide is less soluble in warmer water. What’s more, dissolved carbon dioxide can easily slip back into the atmosphere unless it is taken up by a marine plant or combines with a “buffer” molecule of carbonate.

But the ocean’s supply of carbonate is limited and is replenished only slowly as it is washed into the ocean by rivers that erode carbonate-containing rocks such as limestone. In absorbing those two billion tons of carbon from the atmosphere year after year, the ocean is gradually using up its buffer supply. Jorge Sarmiento, an oceanographer at Princeton University, has been trying to predict the impact of such changes on the ocean’s ability to act as a carbon dioxide sponge. He expects that over the next century, its carbon appetite will drop by 10 percent—and it may ebb much further in the long run.

**With no new help from nature** in sight, perhaps it is time for us to think about creating our own carbon sinks. Scientists have dreamed up plenty of possibilities: planting new forests, for example, which the Kyoto climate treaty would encourage. The approach has already taken root on a grand scale in China, where the government has planted tens of millions of acres since the 1970s. The bureaucrats set out to control floods and erosion, not stem global change, but the effect has been to soak up nearly half a billion tons of carbon.

Steve Wofsy sees another possibility in his forest studies. Young forests like his study plot



**A mirage only a few generations ago in China, a coal-fired power plant blends into the landscape of Shanxi Province. Worldwide CO<sub>2</sub> levels show no sign of diminishing as fast-developing nations clamor for energy.**

are hungry for carbon right now because they are growing vigorously. So why not try to keep a forest young indefinitely, by regular thinning? “You manage it so that every year or every ten years you take out a certain amount of wood” to be used in, say, paper, housing, and furniture, Wofsy says. “You might have a situation where you could make the landscape continue to take up carbon for a long time—indefinitely.”

Then there’s the siren call of the sea. Although as Sarmiento points out the ocean’s natural uptake is dwindling, scientists have tried to find a way to give a boost to its carbon appetite. In the 1980s oceanographer John Martin suggested that across large tracts of ocean, the tiny green



Fire turns carbon from solid to gas,





An aerial photograph of a savanna landscape. A bright orange and red fire line is visible, winding across the terrain from the top left towards the center. The vegetation is a mix of green and brown, indicating a fire-affected area. The sky is a pale, hazy blue.

ready again for plants to inhale.

Imagine an invisible cloud of carbon dioxide rising with the smoke as fire crawls across an Australian savanna. A warmer CO<sub>2</sub>-enhanced climate could spur lush growth in parts of the world. Elsewhere, however, rainfall could ebb, parching forests and leading to even more fires.



# The most fitting end for the carbon that human beings have tapped from the Earth would be to send it back where it came from.

plants that are the marine equivalent of forests and grasslands are, in effect, anemic. What keeps them from flourishing—and perhaps sucking up vast quantities of carbon dioxide—is a lack of iron. Martin and others began to talk of a “Geritol solution” to global warming: Send out a fleet of converted oil tankers to sprinkle the oceans with an iron compound, and the surge of plant growth would cleanse the air of industrial emissions. As the plants and the animals that grazed on them died and sank, the carbon in their tissues would be safely locked away in the deep ocean.

Reality has not been quite so elegant. Experiments have shown that Martin was partly right: A dash of iron sulfate does cause the ocean’s surface waters to bloom with patches of algae tens of miles long, so vivid they can be seen by satellites. But oceanographers monitoring what happens in the water have been disappointed to find that when the extra plants and the animals they nourish die, their remains mostly decay before they have a chance to sink and be buried. The carbon dioxide from the decay nourishes new generations of plants, reducing the need for extra carbon from the atmosphere. Nature is just too thrifty for iron fertilization to work.

Perhaps carbon can be deep-sixed without nature’s help: filtered from power plant emissions, compressed into a liquid, and pumped into ocean depths. Ten thousand feet down, water pressure would squeeze liquid carbon dioxide to a density great enough to pool on the seafloor, like vinegar in a bottle of salad dressing, before dissolving. At shallower depths it would simply disperse. Either way environmentalists and many scientists are wary of the scheme because injecting vast quantities of carbon dioxide would slightly acidify the deep ocean and might harm some marine life. Last year protesters forced scientists to cancel experiments meant to test the idea, first near Hawaii and then off Norway.

But Peter Brewer, who is studying the scheme

at the Monterey Bay Aquarium Research Institute, says it’s too early to write it off. Rising carbon dioxide in the atmosphere will acidify the ocean’s surface waters in any case, he points out, and pumping some of the carbon into the ocean depths could slow that process. “Why would you want to take this off the table before you know what it does?” he asks.

The most fitting end for the carbon that human beings have tapped from the Earth, in coal, oil, and gas, would be to send it back where it came from—into coal seams, old oil and gas fields, or deep, porous rock formations. Not only would that keep the carbon out of the atmosphere, but the high-pressure injection could also be used to chase the last drops of oil or gas out of a depleted field.

In fact geologic sequestration, as it’s called, is already under way. One field in the North Sea, for example, yields gas that is heavily contaminated with natural carbon dioxide. So before shipping the gas, the Norwegian oil company Statoil filters out the carbon dioxide and injects it into a sandstone formation half a mile below the seafloor. The U.S. Department of Energy plans to start its own test project, which would drill a 10,000-foot well in West Virginia and pump carbon dioxide into the deep rock.

No one knows yet how well such schemes might work in the long run. Tapped-out oil and gas fields are, by nature, full of man-made holes that might leak the carbon dioxide. Even if the stored gas didn’t leak straight to the surface, it might seep into groundwater supplies. But the North Sea project seems to be working well eight years after it began. Seismic images that offer







**Signs to the future are coming clearer: Unless societies lessen dependence on fossil fuels, including gasoline-powered highway traffic, the carbon cycle will fly further out of balance and everything—from what we eat to where we live—could change dramatically. Scientists promote remedies like hydrogen-fueled cars and the burial of greenhouse gases, but those are miles down the road.**

views beneath the ocean floor show that the thick layer of clay capping the sandstone is effectively sealing in the six million tons of carbon dioxide injected so far.

That's encouraging news for researchers who are working on schemes that would allow humanity to keep burning fossil fuels without dire consequences for climate. Researchers at Princeton, for example, are exploring a technology that would take the carbon out of coal.

In a multistep process coal would react with oxygen and steam to make pure hydrogen, plus a stream of waste gases. The hydrogen could be burned to produce electricity or distributed to gas stations where hydrogen-powered cars—emitting nothing but water vapor—could fuel up. The waste, mostly carbon dioxide but also


contaminants that coal-burning plants now emit, such as sulfur and mercury, would be buried. The scheme, says Princeton energy analyst Robert Williams, “could make coal as clean as renewable energy, and you can exploit the low cost of coal.”

Or maybe the future lies in fields of solar panels, armies of giant wind turbines, or a new generation of safe nuclear reactors. No one knows, but that gauge in Wofsy's shack tells us that we don't have long to dither. The trees are doing their best, but year by year the flickering red number is climbing. □

**WEBSITE EXCLUSIVE** Delve deeper into the complex, and at times mysterious, workings of the carbon cycle with resources compiled by our Research Division and a listing of related websites at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).



## GREENWICH, CONNECTICUT



Great wealth like that enjoyed on Horse Island (above) breeds a certain degree of envy—but also good deeds. At the Royal Tea and Fashion Show benefit, a Greenwich high-stepper (right) models a \$3,000 gown. Attendees had the dual pleasure of playing dress-up and raising \$50,000 for an elder-care center.



# 06830

## Greenwich Dream Time

BY DAVID RAKOFF

PHOTOGRAPHS BY CATHERINE KARNOW







**With its rolling lawns** and elegant buildings, the campus of the Greenwich Academy is as imposing and beautiful as many full-blown universities. Founded in 1827, Connecticut's oldest school for girls, teaching preschool through grade 12, is a dream of academic girlhood. Even the lacrosse field seems an expanse of perfect, implausible green.

It is an implausible green, as it turns out. The grass is artificial, an indestructible carpet woven atop a bed of synthetic mulch. Reaching down, my fingertips bring up a fine trace of the "soil," a particulate mix of black rubber crumbs. A student walks along, singing a refrain of a song in French. Her lovely voice carries out over the field to a group of stretching athletes. I jump a few times on the ersatz turf and feel a springing weightlessness.

Perhaps this buoyancy is nothing more than the boundless sense of possibility brought on by the affluence that permeates this town. A scant hour from Manhattan by train, Greenwich, Connecticut, is synonymous with wealth in America. A particular kind of wealth; specifically, Old Money—in some sense older than the nation itself. When Paul Revere rode through in 1774 (a year before his famous ride), Greenwich was already 134 years old. Were he making the trip today, he would surely have traded in his nag at the Bentley or Porsche dealerships in town.

Along Greenwich Avenue, the main commercial strip, the sense of long-standing privilege glows as if frozen in amber. The street is redolent of an idealized past (Gap and Banana Republic notwithstanding). Uniformed officers call out "Cross!" when it is safe to do so. The 75-year-old Subway Barber still sports its sign of art deco steel letters; in the front window, chairs in the shape of tiny red convertible roadsters seat its youngest customers.

For purest nostalgia, however, nothing compares to Best & Co., a children's apparel store full of antique toy cars, rocking horses, girls' wide-brimmed straw hats, and boys' seersucker jackets in impossibly small sizes. The original store, established in New York City in 1879, gave up the ghost in 1971. The Greenwich incarnation is all of six years old—not that one would know it. It's a High WASP movie set, a brilliant simulacrum of burnished wood, miniature sofas, and glass display cases imported from New York (as are many of the town's residents). Ironically,



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**Competition is fierce in the Greenwich Cup regatta (top). "It's a rich man's sport," says racer George Schimmenti, "like watching Wall Street." As for the twins' well-tailored yachting suits? "Flea market," says mom Sherry Delany (above).**





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## GREENWICH, CONNECTICUT

Best & Co.'s owner and chief designer is Susie Hilfiger, whose ex-husband, Tommy, has made a fortune outfitting hip-hop kids, the spiritual opposite of this starched primness.

Concern with appearance, contrived or not, fits with the town's reputation as exclusionary. It's an image that wearies and chagrins some residents. One woman asks if I'm going to write "the usual slam," while another leaves a message, hoping I won't be too "sarcastic." People feel duty bound to drive me through Chickahominy, one of the town's working-class neighborhoods. They point out the renovation of a charming old redbrick building for the Boys & Girls Club for underprivileged youth—a project entirely funded by private donations.

"There is ego here, but almost no arrogance," says Diane Terry, a 15-year resident and mother of three who runs an adventure-travel business. Her nuanced distinction is worth understanding. One needs at least a modicum of ego to make upwards of a million dollars a year—which many residents do—while arrogance would be woefully out of place in a town where there is always someone with a good deal more, and a good deal older, money.

That Old Money dominance has shifted, however. Dozens of investment firms have been established in Greenwich, making it a hedge fund capital rivaling Manhattan. More people commute into town than out of it, and only 28 percent of today's residents were even born in Connecticut.

Parsing the Old Money–New Money distinction is ultimately futile. Yet more than one person makes a concerted effort to apologize for the arriviste "McMansions" springing up everywhere. The rap on these newer houses is that they are too opulent, striving vulgarly for Old World legitimacy. But to an outsider they seem indistinguishable from the more established manses. A gray-shingled colossus on the water built with telecommunications money seems no larger and no gaudier than, say, the century-old blinding white replica of the Petit Trianon palace of Versailles.



**Susanna Barron and Fanny DeCoster (above) assess their lemonade stand's liquid assets in the Milbrook neighborhood. "It was a beautiful day, and everyone was out on the street," says Susanna's mother, Eve, a former New Yorker. Those streets offer safe haven: Milbrook has a private security force. Lacrosse fan Lillian Geronimos (left, seated) also left the Big Apple. "It was too hard to raise kids in the city."**





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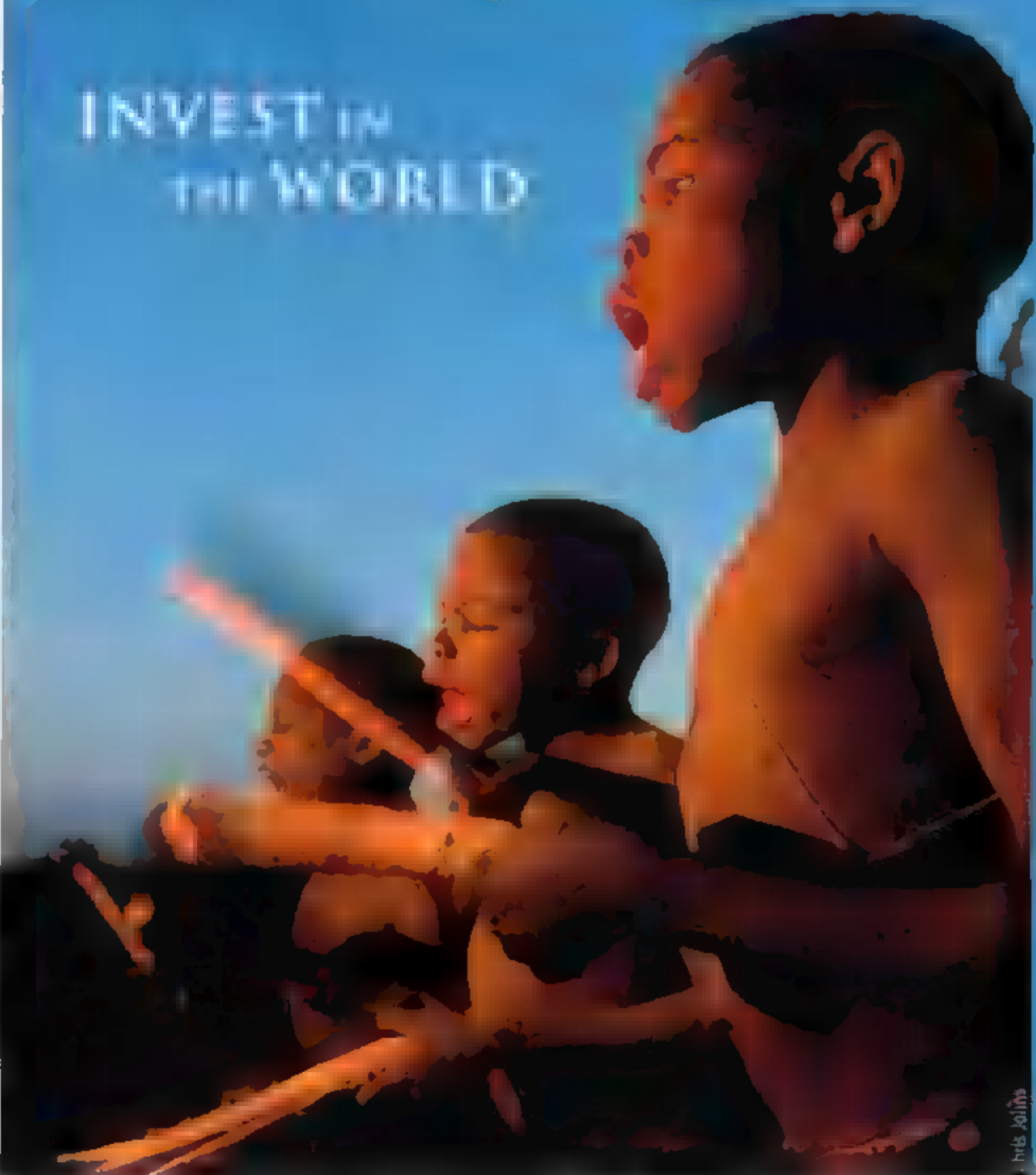


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## GREENWICH, CONNECTICUT



Architect Patricia Balardi Kantorski sits for her portrait, a Christmas gift for her husband. Other tokens of love—such as 10-carat diamond rings—gleam at Betteridge Jewelers on Greenwich Avenue (below). The store commissioned the U.S.-made “Rolex” clock out front. Any other fake Rolexes in town? “Not on my customers,” says store owner Terry Betteridge.

It’s an interesting concept: astronomical wealth as great social leveler. It might explain the marked lack of competition among the 25 debutantes and their parents at the annual Greenwich Cotillion, a fund-raiser for the Junior League. All is a happy buzz as the girls mill about in their long white dresses with bouquets of pink peonies. They wear surprisingly utilitarian hairstyles—lots of sensible comb-outs or plain barrettes. “Most cotillions in America are society driven, with girls included only by invitation or lineage,” says Junior League president Laura Geffs (a “post-deb” from South Carolina). “We don’t turn anyone away.” Indeed, every senior high school girl is invited. Each participating debutante is required to do community service (and each family is required to pony up \$5,000 for a table for ten).

There are military campaigns less carefully planned and executed than the Greenwich Cotillion. At 7:47 the debutantes line up. At 7:55 their fathers enter, peeling off one by one to the strains of “When the Saints Go Marching In.” At 8:05 the young ladies and their escorts advance to “Thank Heaven for Little Girls.” It’s amusing, this use of beloved standards as subtextual commentary. But what can it mean when the music shifts to the beautiful albeit ill-advised choice of the Gershwins’ song for the lovelorn, “But Not for Me”?

At 9:08 the debutantes waltz haltingly with their fathers. The couples bump up against one another sweetly, like apples in a bathtub. The evening’s light drizzle has graduated to full-on torrential. It sounds like applause against the walls of the enormous tent.

In 1640, when Greenwich was founded, the settlers had little idea of the nation whose birth was more than a century away, or of how Greenwich itself would become a shining symbol of that new republic’s most bountiful promise. Even now, the place appears as an almost unattainable dream. □

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# Final Edit



## CARBON CYCLE

### Quiet Time

Is it possible for a photograph to be too tranquil—or even too beautiful? To meet the needs of some articles, the answer is yes.

While developing the layout for the carbon cycle story, design editor Elaine Bradley experimented with a poetic approach. She tried beginning the article with Peter Essick's image of a decomposing leaf in swirling water (the picture that's now on page 103). Early on, Peter's dreamy picture of an egret wading off shell-laden rocks on Florida's Sanibel Island (above) seemed to fit the story's mood.

At the last moment, she and photo editor Dennis Dimick chose a new tack to "ramp up the energy of the story," says Dennis. They changed the opening picture to one of a blazing fire. Then they moved another of Peter's shots from Sanibel onto the next spread—not this quiet still life with the egret, but one with crashing waves—launching the story with speed and drama.

#### WEBSITE EXCLUSIVE

Cut it or keep it? Find out more about what tipped the balance for this photo and send it as an electronic greeting card in Final Edit at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).





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# GOVERNMENT

C O V E R I N G T H E W O R L D



HAN DYNASTY

## A Man With a Following

*Photographer helps the crowd take a wider view*

While retracing the route of the Han dynasty's Silk Road in western China, photographer **Rob Clark** (left) found out that his own route was of interest to the area's modern residents. Shooting on market day in the village of San Bao Xiang, Rob—who shared story coverage with photographer **Lou Mazzatenta** (below)—suddenly noticed that the noisy street he was on had gotten quieter. “Then I realized this whole



LOU MAZZATENTA (LEFT) / WANG BAO PING

crowd of men was following me as I walked across the road,” says Rob. “The smallest guy in the group was finally curious enough to ask to see my camera. The view he saw through the wide-angle lens really surprised him.”



GREENWICH, CONNECTICUT

## Happily Ever After

Kids don't always dress like fairy princesses in posh Greenwich, Connecticut. But childhoods there do seem charmed, says photographer **Catherine Karnow**, here trying on a six-year-old resident's fairy finery. "Greenwich is beautiful and idyllic, with a strong sense of community," Catherine says. "It reminds me of a time when the world was a safer place."

Catherine knows all about charmed childhoods, since she had one herself. Born in Hong Kong, she was raised in a little fishing village outside the big city. "Everything was small,"



ANDREW DOUGLAS SULLIVAN

she remembers, "our house, our garden, even the road to the village was short." But visitors to the Karnow home weren't just the local villagers. "I grew up with famous *Life* photographers around all the time," says Catherine, whose father, noted

journalist Stanley Karnow, was the magazine's Hong Kong bureau chief. Her mother, Annette, is a painter. "I'm a combination of the two," Catherine says. "I get my visual sense from my mother and my journalistic one from my father."

## WORLDWIDE



MOSESE DELAIMATUKU

Can ■ Canadian who specializes in Arctic photography find happiness shooting under ■ relentless equatorial sun? **Paul Nicklen**, at right, did—eventually. On assignment in the South Pacific to cover the Phoenix Islands, he earned the nickname "Frosty" from his shipmates. "because they thought I looked like I was melting." He and **Joe Stancampiano**, at left, the *GEOGRAPHIC*'s photographic

engineering wizard, even sought shade under the bow of their inflatable boat. But, Paul says, "in many ways, it was paradise."

■ wasn't such ■ paradise for Joe. Though he often goes along on underwater assignments to lend photographic and lighting expertise, he has a history of seasickness. "I think the only body of water I haven't been sick on is the Arctic Ocean," says Joe,

"and that's just because it was frozen solid."

After 15 years of observing polar bears, photographer **Norbert Rosing** has learned to tell some of them apart. "Some have an ear missing from fighting. Others have scars on their noses. Some are slimmer, with longer legs. Some are like a huge walking drum."

Norbert has also learned bear behavior, because a good photography season "is all up to the bears and the weather." Cold and snow encourage lots of photogenic play. "When it's too warm," he says, "the bears fight ■ bit, get overheated, and just lie down for hours. And that's not a picture."

**WEBSITE EXCLUSIVE** Find more stories from our authors and photographers, including their best, worst, and quirkiest experiences, at [nationalgeographic.com/magazine/0402](http://nationalgeographic.com/magazine/0402).



From left to right: FourTrax Recon® ES, Honda BF225 Outboard Engine, Honda S2000, AquaTrax™ R-12X, Honda Accord EX Coupe, Gold Wing®, Honda Harmony® HRB217HXA Lawnmower, Acura MDX with Touring Package, Honda Trimmer HHT25SLTA, Honda Super Quiet EU3000IS Generator. ©2003 American Honda Motor Co., Inc. honda.com



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# Flashback



A. SEGERS

## HAN DYNASTY

### All Fired Up

A bed by night, a seat by day, and always a source of warmth, the *kang*, a masonry platform—its origins possibly reaching back to the Han dynasty—was once common in rural north China. Smoldering coals beneath a brick surface generated heat. Here, Chinese sleep at a country tavern. An adjacent photograph in the June 1927 *GEOGRAPHIC* showed guests awake on the kang, rice bowls in hand. “At mealtimes small, low tables are placed upon it, and at night numerous mats convert it into a warm, hard bed,” the photo caption explained. The pillows, noted the photographer, “are filled with millet and are very hard.” —Margaret G. Zackowitz

#### WEBSITE EXCLUSIVE

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Taking a low-dose  
aspirin a day for  
your heart can be a  
smart thing to do.

Taking a pain  
reliever that won't  
interfere with it is  
even smarter.

More and more of you are taking a low-dose aspirin for your heart. Smart. But did you know that if you are also taking ibuprofen, you may not be getting the cardio protection you seek?

Clinical studies have shown that under certain circumstances, frequent use of ibuprofen can actually interfere with your aspirin therapy. It may be blocking your aspirin's ability to thin your blood.

If you are taking a low-dose aspirin a day for your heart, Tylenol may be a better choice. Unlike ibuprofen, Tylenol has not been shown to interfere with your aspirin heart therapy. That's why most doctors recommend Tylenol for people on aspirin therapy. Talk to your doctor about what's right for you.

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A Better Choice.



# First sight.

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